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Tech Notes

MAY 1988

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Tech Notes

Highlighting Selected U.S. Government Technology & Resources

MAY 1988

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Published monthly by the National Technical Information Service (NTIS), Tech Notes bring together individual one to two page fact sheets prepared by Federal agencies, their laboratories, or contractors. These fact sheets highlight current Federal technology determined to have commercial or practical application. Topics cover new processes, materials, techniques, software, instrumentation, and resources.

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Sources of Further Backup Information

Below are two representative examples of how each Tech Note fact sheet provides you with a source of further information. In most cases, this information is provided directly by the agency or its laboratory. However, there are cases where NTIS is the source for backup documentation. In these cases, use the order form at the end.

Examples:

significant distance from the endwalls. Therefore, a radial variation in efficiency should be used when designing small stators.
Project Officer Jeffrey E. Haas
(216) 433-4000.

FOR ADDITIONAL INFORMATION

You can learn more about this technology by ordering the NTIS report(s):
Cold-Air Performance of Compressor Drive Turbine
Order number: AD-A101066/NAA
Price code: A02
Order from:
National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
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Agency contact who can supplement the information contained in the backup report.

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* See the order form and price code table at the end of the issue.

Suggested applications include other kinds of refrigerators, heat engines, thermal instrumentation, and heat switches.
This work was done by Emanuel Tward of Caltech for NASA's Jet Propulsion Laboratory.
NPO-15479/TN

FOR ADDITIONAL INFORMATION
Contact: Director, Technology Transfer Division, P.O. Box 8587, BWI Airport, MD 21240: (301) 621-0100 Ext.241.
REFER TO THE NUMBER LISTED AT THE END OF THE ARTICLE

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Source of more information about the technology described in the fact sheet

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354 Reliable Wiring Harness — Materials and design are changed for immunity to vibration and corrosion. (Licensing Opportunity)

355 Self-Identifying Emergency Radio Beacons — Rescue teams are aided by knowledge of the vehicle in distress. (Licensing Opportunity)

356 Solar-Powered Sensor Module — A hybrid sensor module with no external electrical interconnections includes an optical data link. (Licensing Opportunity)

357 Variable-Speed, Constant-Frequency Generation of Power — Feedback of the stator power and reactive volt-amperes determines the rotor excitation.

Software

358 Calculating Electromagnetic Fields of a Loop Antenna — Approximate field values are computed rapidly.

359 Computing Radiation Characteristics of Phased Arrays — Radiated powers, directivities, and radiation patterns can be calculated.

360 Designing Digital Filters — A computer program calculated a performance index from magnitude and phase errors.

361 Designing Rectangular RHCP Microstrip Antennas — A program calculates the configuration and the impedance.

362 Locating Spaceborne SAR Imagery — An arbitrary picture element can be located precisely.

363 PCACE–Personal-Computer-Aided Cabling Engineering — Routine aspects of the design of wiring harnesses are automated.

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364 Simple Model Computes Spectral Solar Radiation

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367 Assessment of Advanced Concentrator Photovoltaic Modules — Many designs are analyzed in terms of cost and efficiency.

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369 Luminance Mapper Model 2

370 Compact Sun-Position Sensor — A single device finds and tracks the sun. (Licensing Opportunity)

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374 Acoustic Solid/Gas Flowmeter — Direct monitoring in solids transport lines.

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377 Collector/Compactor for Waste or Debris — A stretchable net gathers loose material and compresses it.

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380 Effects of Structural Errors on Parameter Estimates — The information content of a measurement is defined.

381 Repairing Holes in Pressure Walls — Patches and easy-to-use tools yield a pressure-tight seal. (Licensing Opportunity)

382 Steam Reformer with Fibrous Catalytic Combustor — Heat transfer would be more controllable. (Licensing Opportunity)

383 Truss-Core Corrugation — The strength-to-weight ratio exceeds that of the beaded-web design by 60 percent. (Licensing Opportunity)

Software

384 Calculating Transport of Moisture Through Honeycomb Panels — Diffusion equations are solved for steady-state and transient conditions.

385 Steady-State Thermal-Analysis Program for Microcomputers — A nodal-network model of heat flow is implemented by a computer program.

Testing & Instrumentation

386 Portable Test and Monitoring System for Wind-Tunnel Models — Model instrumentation can be tested in or out of the wind tunnel. (Licensing Opportunity)

387 Water-Tunnel Flow Visualization with a Laser — Experimental conditions for effective visualization are determined. (Licensing Opportunity)

Other Items of Interest

343 Position and Force Control for Multiple-Arm Robots — The number of arms can be increased without introducing undue complexity.

429 Swivel Joint for Liquid Nitrogen — The joint is compatible with hard foam insulation.

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390 Prediction of Oil Spill Transport

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Manufacturing, Machinery, & Tools

392 Studies of Oxide Dispersion Strengthening of Aluminum Alloys

393 Vacuum Plasma Spray Overlay Coatings

394 Contamination-Free Electrical-Discharge Machining — Debris are swept into the electrode by the flow of coolant. (Licensing Opportunity)

395 Pin Inserts for Plug Welds — Leakage through minute cracks is eliminated.

396 Protective Coating for Laser Drilling of Silicon — Sodium silicate prevents spattered silicon from fusing with surrounding material.

397 Tool Removes Arc-Light Reflectors — Self-clamping reflectors are easily removed from welding torches. (Licensing Opportunity)

Testing & Instrumentation

398 Optoelectronic Proximity Sensor Finds Edges — Seams are tracked for automatic control of welding. (Licensing Opportunity)

399 Holding X-Ray Film Inside Ducts — A simple, easy-to-use device speeds inspection. (Licensing Opportunity)

Other Items of Interest

400 Effect of Manufacturing Processes on Structural Allowables

404 Active-Substrate Brazing Process

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400 Effect of Manufacturing Processes on Structural Allowables

401 Effects of Plastic Bead Paint Removal on Properties of Aircraft Structural Materials

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410 Ceramic Adhesive for High Temperatures — The fused-silica/magnesium-phosphate adhesive resists high temperatures and vibrations.

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412 Glass-Bead Blasting Alters Antenna Surface — Thermal-emissivity properties are improved, and focal length is adjusted.

413 Polyphenylquinoxalines Containing Alkylenedioxy Groups — Better processability is achieved through the lowering of glass-transition and melt temperatures. (Licensing Opportunity)

414 Thermosetting Fluoropolymer Foams — Uses include coatings, electrical insulation, and structural parts. (Licensing Opportunity)

Software

415 ICAN: Integrated Composites Analyzer — This program calculates macromechanical, micromechanical, and related environmental effects.

416 Laminate-Moisture-Analysis Computer Program — The diffusion and the deleterious effects of moisture can be predicted.

Testing & Instrumentation

417 Slow Neutron Reflectometer (POSY II) — New application of neutron reflection techniques measures interdiffusion of polymers.

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419 Antigen Delivered by Biodegradable Polymers may Provide Long-Lasting Immunity

420 Copper and Penicillamine Cluster Ion has Potential Applications in Both Diagnostic Imaging and Therapy

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368 Atmospheric Optical Calibration System Simplifies Spectral Measurements

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426 Convective Evaporation of Sprayed Liquid — The behavior of clusters of drops is analyzed.

427 Air Revitalization Using Superoxides — $Ca(O_2)_2/KO_2$ pellets are superior to KO_2 pellets for air revitalization. (Licensing Opportunity)

428 Predicting Visible Range of an Object — The relative angles of light sources and object orientation are taken into account.

429 Swivel Joint for Liquid Nitrogen — The joint is compatible with hard foam insulation.

430 Tunable Dual Semiconductor Laser — Parallel lasers interact in shared space to alter output wavelength. (Licensing Opportunity)

Software

431 Computer Program Calculates Long Wavelength Propagation

432 Calculation of Multicomponent Convective Diffusion Deposition — A computer program calculates rates of deposition of vapors or by small particles.

433 Calculating Thermodynamic and Transport Properties of Fluids — A computer program incorporates a van der Waals equation and correction tables.

434 Improved General Chemical-Kinetics Program — More computational power is brought to bear on complicated, homogeneous ideal-gas reactions.

435 Star-Tracker Computer Program — Image-analyzing systems can be aimed to high precision.

Testing & Instrumentation

436 A Low-Volume Insert for Solid-State Magic Angle Spinning NMR of Small Samples

437 IMAGESystem — Improved imaging and data handling for gel electrophoresis.

438 Apparatus for Ultrasonic Nebulization (Licensing Opportunity)

439 Explosives Sensor

440 Sulfide Detection Apparatus (Licensing Opportunity)

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409 Advances in Thermoelectric Materials — Fare-earth chalcogenides and boron-rich borides show promise.

413 Polyphenylquinoxalines Containing Alkylenedioxy Groups — Better processability is achieved through the lowering of glass-transition and melt temperatures. (Licensing Opportunity)

414 Thermosetting Fluoropolymer Foams — Uses include coatings, electrical insulation, and structural parts. (Licensing Opportunity)

417 Slow Neutron Reflectometer (POSY II) — New application of neutron reflection techniques measures interdiffusion of polymers.

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Software

441 Numerical Simulation for Supersonic Inlets — Flows are calculated for realistic engine-inlet conditions.

442 Simulation of the Internal-Combustion Engine — This program adapts to the available information about a particular engine.

Other Items of Interest

401 Effects of Plastic Bead Paint Removal on Properties of Aircraft Structural Materials

Agriculture & Food

341 A Fungal Foe for Jimsonweed (Licensing Opportunity)

342 Prototype Forage Mat Machine Mows and Shreds Alfalfa: Mat Dries Quickly Allowing Same Day Baling

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United States Department of Agriculture

Research Technology
Agricultural Research Service

A Fungal Foe for Jimsonweed

Jimsonweed is a notorious weed native to the eastern half of the United States. Not only does it compete with soybeans and cotton, but its foliage and seeds contain alkaloids that can harm livestock and humans. Many of today's herbicides don't work well on jimsonweed; once it matures, it stubbornly resists control. However, a fungus, *Alternaria crassa*, has been found to be pathogenic to jimsonweed but essentially harmless to crops.

Patent-applied-for methods to intentionally spread this weed-walloping fungus may save thousands of dollars in wasted herbicides. The fungus, in the form of dormant spores, is broadcast on vegetation, where it will selectively destroy jimsonweed. Several means of application are possible: water-based and oil-based liquid sprays, granules, and gel pellets.

Not only is the fungus safe for soybeans and cotton, researchers were able to verify that *A. crassa* does little harm to most garden plants. Out of seven families of crops, only one variety of tomato died after being exposed to the fungus.

For Additional Information:

To discuss this effort further, contact:

Clyde Boyette,
USDA Delta States Research Center,
P.O. Box 350
Stoneville, MS 38776; (404) 546-3322

For inquiries concerning rights for the commercial use of this invention should be addressed to

Office of Federal Patent Licensing
Center for the Utilization of Federal Technology
Room 13R, NTIS
Springfield, VA 22161; (703) 487-4738

Refer to Patents 7-092,100/TN

United States
Department of
Agriculture

Research Technology
Agricultural Research Service

Prototype Forage Mat Machine Mows and Shreds Alfalfa: Mat Dries Quickly Allowing Same Day Baling

A new machine could increase forage value and save farmers time by letting them mow hay in the morning and bale it in the afternoon instead of days later, report scientists at the U.S. Department of Agriculture.

The prototype "forage mat machine" mows alfalfa and immediately shreds it, said one of the researchers, Agricultural Engineer Richard G. Koegel of USDA's Agricultural Research Service.

"The machine presses the shredded leaves and stems into a continuous, quarter-inch-thick mat and lays it on the stubble to sun-dry in six hours or less," he said. "The hay could be baled the same day."

That means less chance of rain damage to the crop, said Koegel of the U.S. Dairy Forage Research Center in Madison, Wis. With a conventional mower-conditioner, two to four days are needed to sun-dry alfalfa to the 20 percent moisture content needed for baling, said Koegel.

"The machine mixes leaves and stems into a homogenized material that dries quickly and uniformly," he said. There is a tendency with conventional methods for the leaves to dry faster than the stems causing them to shatter and be lost during harvest. Hay processed by the new machine and fed to sheep was about 15 percent higher in fiber digestibility than forage cut and dried with conventional methods, he said.

Koegel and his colleagues at the University of Wisconsin-Madison developed the mower-shredder-matmaker-layer over the last five years.

After sun-drying, the hay is ready for harvesting by conventional methods, if desired.

The machine will be available to farmers when farm equipment manufacturers begin commercial development. Presently, one manufacturer is working on developing the machine.

FOR ADDITIONAL INFORMATION: To discuss this effort further, contact Richard G. Koegel, research agricultural engineer, U.S. Dairy Forage Research Center, Madison, WI; (608) 263-5636.

Computers

343 Position and Force Control for Multiple-Arm Robots — The number of arms can be increased without introducing undue complexity.

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347 Interactive Plotting Program — Plots can be edited before printing.

348 Tape-Certification Program — Magnetic tape is tested at various data densities.

NASA Tech Brief
National Aeronautics and Space Administration
NASA's Jet Propulsion Laboratory, Pasadena, California

Position and Force Control for Multiple-Arm Robots

The number of arms can be increased without introducing undue complexity.

A strategy and a computer architecture have been developed for the simultaneous control of the positions of a number of robot arms manipulating the same object and of the forces and torques that the arms exert on the object. The scheme will enable coordinated manipulation of the object, causing it to move along an assigned trajectory and be subjected to the assigned internal forces and torques.

The basic principle is illustrated by the simplified example of a one-dimensional, frictionless system with a mass in contact with two actuators (see Figure 1). The servocontrol loop causes the actuators to apply forces F_1 and F_2 to the mass in an attempt to make it accelerate at a desired rate. The control imposes the condition that the total actuator force, $F_1 + F_2$, must equal F, the force necessary to produce the desired acceleration of the total system mass, which is the sum of the point mass plus the effective work-space masses of the actuators.

The control algorithm imposes the specified relationship between F_1 and F_2. For example, if it is desired to squeeze the object with a force F_p while accelerating it, then the control system will continually strive to readjust F_1 and F_2 to make $F_1 - F_2 = F_p$. If the object is constrained against moving, then F_1 and F_2 can be set to arbitrary values or subjected to an arbitrary criterion.

In the general case, n robot arms make contact with a body of finite size (see Figure 2). In this case, the body rotation and the linear motion of a point G on the body are specified, and the control algorithm apportions the forces, or torques, or both among all n arms. Of course, the equations of motion and the specifications of constraints (planes of contact and sliding, axes of rotation, robot-joint configurations, and the like) are more complicated in the n-arm case: In general, a dedicated microprocessor would be required to solve continually the motion and control-force equations for each arm.

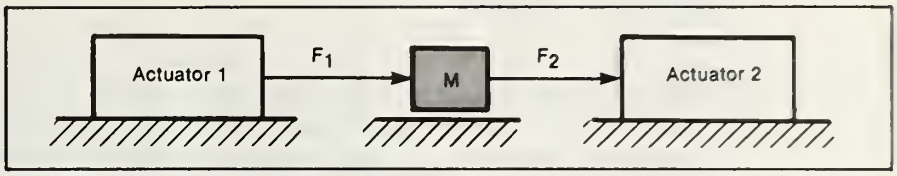

Figure 1. A **Mass, M, on a One-Dimensional Track** is pushed and/or pulled by either or both of two actuators. The control algorithm for this system imposes forces F_1 and F_2 subject to specified conditions on the motion and the squeezing or stretching of the object.

Each of the n arms is considered to be attached rigidly to the object. A portion of the object in contact with each robot arm is treated, for control-algorithm purposes, as the last link in that arm. Thus, a portion of the mass and of the inertia tensor of the object is mathematically assigned to each arm.

As in the one-dimensional example, the equations of motion are solved for the force and torque that must be exerted by each arm to obtain the desired motion. In this case, however, the sum-of-forces (and/or torques) condition applies to all n arms. The difference-of-forces (and/or torques) condition is distributed among all arms so that each arm cooperates with the other arms to produce the desired internal forces or torques.

Instead of a difference-of-forces (or torques) condition it is possible to impose other arbitrary force/torque conditions, as long as the total forces and torques continue to satisfy the equations of motion. For example, one can require that a weighted sum of squares of forces, or some other performance index, be minimized.

The control scheme is well suited for a distributed computer architecture. Because the number of microprocessors required increases only linearly with the number of robot arms, in principle the finite nature of computing resources imposes no limit on the number of robot arms.

This work was done by Samad A. Hayati of Caltech for **NASA's Jet Propulsion Laboratory**.

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to

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Director of Patents and Licensing
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California Institute of Technology
1207 East California Boulevard
Pasadena, CA 91125
Refer to NPO-16811, ITN

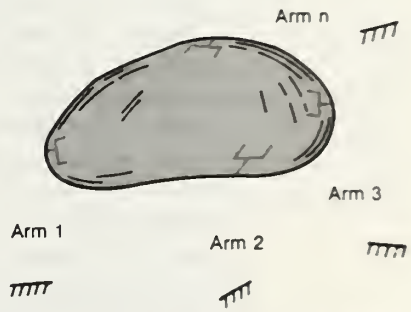

Figure 2. A **Number of Robot Arms** cooperate in manipulating an object. The control scheme apportions the contact forces and torques among the arms to produce the desired motion of the object, and the desired forces and torques inside the object.

FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD. 21240; (301) 621-0100 Ext. 241*
REFER TO THE NUMBER LISTED AT THE END OF THE ARTICLE

NBS technology update

National Bureau of Standards
U.S. Department of Commerce
Gaithersburg, MD 20899

Computer Software

Microcomputer Program Selects Optimal Service Center Sites

NBS mathematicians have developed a set of computer programs for the Internal Revenue Service (IRS) which attacks a problem common to many national, service-oriented businesses: the selection of locations for service centers that reach the largest number of clients at the least cost in travel and basic expenses. The system uses postal zipcodes to define geographic areas, and can consider such factors as travel costs, office rental costs, and the costs of opening or closing existing centers. The system includes a graphic display driver for IBM-compatible computers, written in FORTRAN, and the basic problem solving program, written in PASCAL. Although these programs are designed specifically for the IRS, the basic algorithms and techniques could be applied to many commercial problems.

FOR ADDITIONAL INFORMATION: The system is described in a series of four NBS reports, summarized in The Internal Revenue Service Post-Of-Duty Location Modeling System - Final Report (NBSIR 86-3482), available from the National Technical Information Service, Springfield, VA 22161. To discuss this effort further, contact: Dr. Richard Jackson, A1002 Administration Bldg., National Bureau of Standards, Gaithersburg, MD 20899; (301) 975-2659.

NTIS order number: PB88-112420/NAC
Price code: A03

Goel-Okumoto Nonhomogenous Poisson Process Software Reliability Model

Software reliability models are most useful during the testing phase of a software development project. They answer such questions as "how many more failures will be seen if testing continues for a specified time period," "what is the current reliability of the software," and "what will the reliability of the software be if it is tested for an additional specified time period." Although the use of a technology that answers such questions is readily apparent, software reliability models tend not to be in widespread use, partly because they are often presented in terms of theory not readily understood by those not specializing in these models. One way to promote the transition of reliability models into more widespread use, therefore, is to present the models in an easy-to-use, automated fashion.

The DACS recently developed an automated version of the Goel-Okumoto Nonhomogeneous Poisson Process Software Reliability Model. This model is mathematically elegant, has parameters with a comprehensible physical interpretation, and does not require any assumptions about the dimensions in which time is measured. The automated model runs on an IBM-PC or compatible under MS-DOS 2.11 or higher. Features include the ability to find maximum likelihood estimators of the parameters defining the model by using either the Newton-Raphson or Muller's method; a goodness-of-fit test based on a Kolmogorov-Smirnov statistic; estimation of remaining faults, cumulative failures, and reliability; 95% and 99% confidence bounds on these estimates; and estimation of the optimal release time based on certain cost criteria. The program runs under an easy-to-use menu interface. The model requires as input either the number of failures observed in successive, equal length time periods (preferred) or the time between successive failures.

FOR ADDITIONAL INFORMATION: This implementation of the Goel-Okumoto Model is available from the DACS for $50 shipped UPS or $55 shipped First Class mail. Contact Mr. Robert Vienneau at the DACS for additional information on this product:

Data & Analysis Center for Software
RADC/COED
Griffiss AFB, NY 13441-5700
ATTN: Goel-Okumoto Model
(315) 336-0937

Generating Cross-References Among Computer Routines

This program helps a user search a library of computer programs.

The Cray Library Load Cross-Reference (CROSSREF) computer program is a tool that assists users in obtaining information about subroutines in a computer-program library. Maintaining a library of computer routines requires an understanding of the relationships between the modules of code. CROSSREF uses tables generated by the Cray operating system BUILD command to cross-reference the routines by tabulating routine names, EXTERNALS, COMMONS, and ENTRY POINTS.

CROSSREF creates alphabetized listings and tables that yield information about each member of the library. Summary tables, a table of contents, and library statistics are also produced. The user has the option to include or exclude Cray system EXTERNALS in the cross-reference lists. The output can be directed to either 132-character printer paper 11 or 8½ in. (27.9 or 21.6 cm) high or a cathode-ray-tube display. CROSSREF can accommodate libraries of up to 4,096 modules.

The CROSSREF program is written in FORTRAN IV for batch execution and has been implemented on a Cray X-MP 22-series computer (dual CPU) under COS. CROSSREF was developed in 1984.

This program was written by Clayton Guest of Informatics General Corp. for **Ames Research Center**.

ARC-11591 /TN

FOR ADDITIONAL INFORMATION
CONTACT:

COSMIC®
112 Barrow Hall
University of Georgia
Athens, GA 30602
(404) 542-3265

Interactive Plotting Program

Plots can be edited before printing.

The Interactive Plotting Program (IAP) provides a fast and easy method of plotting data in a presentable format. Extensive plot editing can be done with the various IAP commands, which may be typed interactively from the terminal or read from batch command files. The ability to redirect output to a variety of devices enables the user to tailor plots with a graphics terminal before printing. IAP is designed to allow the addition or deletion of code for any type of terminal or plotting device.

Optional features are included to make the program as flexible as possible, but simple graphs can be made by using only two commands. Options include (1) a choice of 27 standard Hershey character sets; (2) labels, legends, and titles; (3) grids, scaling, and log axes; (4) pen color; (5) data sorting; (6) shrink factors; and (7) multiple overlays. All options in the program have default settings; i.e., labels, scales, character types, and plot symbols can be supplied automatically.

A user of IAP enters a series of commands to tailor the plotting of up to nine graphs on any graphics device attached to the computer. The plotting device is allocated only while being used, allowing other users to share the resources of the system. Data are read into the program from user-produced ASCII data files with a single X-Y point per record. IAP allows plottable sets of data of up to 2,048 points per set, with up to nine sets in one plot. Larger sets of data can be handled with the SAMPLE command to plot only every Nth data point. The HELP command delivers information on any IAP command. DCL commands can be executed from within IAP.

IAP is written in FORTRAN 77 and Assembler for batch or interactive execution and has been implemented on a DEC VAX computer under VMS. IAP currently has code for DEC VT125, VT240, HP 2648A, HP 7475, Tektronix 40XX, and Ramtek Colorgraphics terminals. Versatec 1200 and Grinnell devices are also supported but require the commercial Versatec or Grinnell graphics software packages. IAP was developed in 1986.

This program was written by Judith G. Moore of Wyle Laboratories for **Langley Research Center**. *LAR-13655 /TN*

FOR ADDITIONAL INFORMATION *CONTACT:*

COSMIC®
112 Barrow Hall
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Athens, GA 30602
(404) 542-3265

Tape-Certification Program

Magnetic tape is tested at various data densities.

A tape-certification program tests the usability of magnetic tape at different densities by writing test patterns and rereading them. The ability to certify tapes is important in computer systems that do large amounts of tape processing. A certification program is a cost-effective alternative to a tape-certification machine. TAPECERT is a VAX utility program for tape certification in use at the Jet Propulsion Laboratory Multi-Mission Image Processing Laboratory (MIPL), which processes data from such projects as Voyager and Galileo. MIPL maintains a library of some 80,000 tapes.

TAPECERT allows the user to select the tape density, the test pattern to use, and the number of allowed retries, and to decide whether to allow extended inter-record gaps to skip past bad spots on the tape. The program displays system error messages (parity errors, for instance) and record-count information with totals every 1,000 blocks. TAPECERT is designed so that command procedure can be set up with defaults for different types of certification runs.

TAPECERT is written in FORTRAN 77 and utilizes standard VMS system services and run-time library routines. It has been implemented on DEC VAX-series computers operating under VMS levels 3.7 and 4.2. This program was developed in 1985.

This program was written by Scott E. Fullner of Caltech for **NASA's Jet Propulsion Laboratory**. *NPO-16876 /TN*

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Electrotechnology

349 TEMPO used at Medical, Electronics, and Defense Facilities

350 Details Available on Superconducting Contacts

351 Distress Transmitter and Receiver — Identifying distress signals are sent and received automatically. (Licensing Opportunity)

352 Extension of Subreflector Increases Antenna Efficiency — The subreflector is widened up to about one wavelength beyond the optical limit.

353 Cavity-Modulation Autotuner for Hydrogen Maser — Resonance is maintained without incidental frequency modulation.

354 Reliable Wiring Harness — Materials and design are changed for immunity to vibration and corrosion. (Licensing Opportunity)

355 Self-Identifying Emergency Radio Beacons — Rescue teams are aided by knowledge of the vehicle in distress. (Licensing Opportunity)

356 Solar-Powered Sensor Module — A hybrid sensor module with no external electrical interconnections includes an optical data link. (Licensing Opportunity)

357 Variable-Speed, Constant-Frequency Generation of Power — Feedback of the stator power and reactive volt-amperes determines the rotor excitation.

Software

358 Calculating Electromagnetic Fields of a Loop Antenna — Approximate field values are computed rapidly.

359 Computing Radiation Characteristics of Phased Arrays — Radiated powers, directivities, and radiation patterns can be calculated.

360 Designing Digital Filters — A computer program calculated a performance index from magnitude and phase errors.

361 Designing Rectangular RHCP Microstrip Antennas — A program calculates the configuration and the impedance.

362 Locating Spaceborne SAR Imagery — An arbitrary picture element can be located precisely.

363 PCACE–Personal-Computer-Aided Cabling Engineering — Routine aspects of the design of wiring harnesses are automated.

Other Items of Interest

408 Process Developed for Making Superconductors

412 Glass-Bead Blasting Alters Antenna Surface — Thermal-emissivity properties are improved, and focal length is adjusted.

430 Tunable Dual Semiconductor Laser — Parallel lasers interact in shared space to alter output wavelength. (Licensing Opportunity)

Sandia National Laboratory

TEMPO used at Medical, Electronics, and Defense Facilities

A high-voltage machine for generating repeating pulses of microwaves up to 10 times a second has been designed at Sandia National Laboratories. Three of the machines, called TEMPO, have been built at Sandia and are being used in Army and Air Force research programs in Washington, D.C.; Maryland; and New Mexico.

The megavolt TEMPO machine was designed for burst-mode operation with output pulses of 100-nanosecond duration at pulse repetition rates of 1 to 10 times a second. The TEMPO name was derived from "*T*ransformer-*E*nergized *M*egavolt *P*ulsed *O*utput."

"TEMPO is the first rep-rated high-powered microwave driver in the country," says Gerald J. Rohwein of Sandia's Pulsed Power Components Division. In addition to its high repetition rate capability, the machine was designed for ease of operation. "It's user friendly," says Rohwein. "It is probably the only pulsed-power system of its kind designed as a turnkey system."

Single command initiates

Machine controls are partially automated so that an operator need only preset switch pressures, pulse count, pulse repetition rate, and charge voltage level. A single command signal initiates a sequence that energizes the charging modulator, opens gas valves, charges the primary capacitor bank, and delivers a programmed series of pulses to the machine's timing and firing circuit. When the burst is complete, the control system shuts down the system.

The semiautomatic controls provide almost exact reproducibility from one test run to the next, its designers say. The machine also makes use of a new type of all-solid-state power supply that helps ensure pulse stability.

The three existing TEMPO machines are currently in use at

—Walter Reed Army Medical Center, Washington, D.C. Its machine is being used for biomedical research into effects of high-powered microwaves on organisms and organs.

—U.S. Army Harry Diamond Laboratory, Maryland. Used as a test bed for developing advanced microwave generators and for electronics-systems vulnerability testing.

—Air Force Weapons Laboratory, Albuquerque, New Mexico. Used for microwave systems development and testing of weapons systems for microwave vulnerability.

These were built as part of a Cooperative Program in High Power Microwave Technology Development between the Department of Energy and the Department of Defense.

Uses parallel Blumleins

TEMPO is a fairly compact high-powered microwave generator. The core of the machine is a pulse-forming transmission line that is housed in a tank about 9 ft long. To meet the size constraints and the other performance characterizations, the pulse-forming transmission line was designed as two parallel water-insulated, strip-line Blumleins. (A Blumlein is a voltage-doubling transmission line.)

Stray capacitance and electric fields along the edges of the strip lines were controlled by lining the tank with plastic sheet. A transformer and a 30-kilovolt primary capacitor bank that charge the Blumlein are located at the rear of the machine.

At the front is a vircator microwave converter designed by M. Collins Clark and Larry D. Bacon of Sandia's Microwave Physics Division. It converts TEMPO's high-voltage electrical pulses into high-power microwaves that are transmitted through a waveguide to an antenna.

Rohwein and Sandia colleagues Kim T. Lancaster and Robert N. Lawson developed the TEMPO high-voltage pulse generator.

FOR ADDITIONAL INFORMATION

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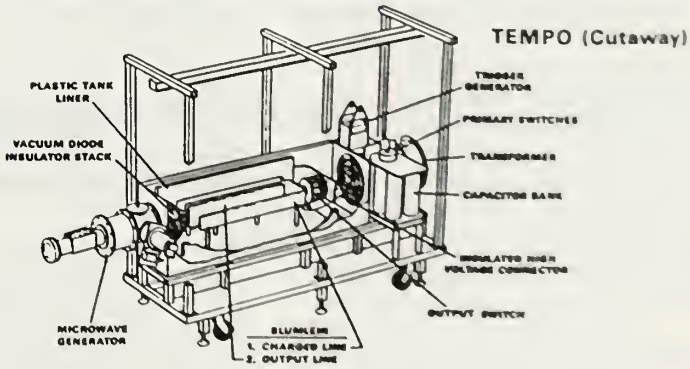

NBS technology update

National Bureau of Standards
U.S. Department of Commerce
Gaithersburg, MD 20899

Details Available on Superconducting Contacts

The high resistance that usually occurs where external leads are attached to ceramic superconductors is an obstacle to both measurements and practical applications of the newly developed high-critical-temperature superconductors. Work by NBS and the Westinghouse Research and Development Center, Pittsburgh, Pa., has produced a new method for making low-resistance electrical contacts on ceramic superconductors. The researchers developed the new method after noticing there was a correlation between the ages of many superconductor samples and their contact resistivities. The new method involves three parts, which work together to produce low contact resistivity. Minimizing the air exposure time minimizes the degradation of the superconductor surface that occurs before making the contacts. Sputter etching the surface removes the degraded layer, and depositing a thin layer of a noble metal--silver and gold were used--protects the surface and minimizes further degradation of the superconductor surface. When the method was tried on old samples exposed to air for over 2 months, the contact resistivity was about 10 times higher than for contacts formed on fresh samples only an hour old. A deeper sputter etch may be necessary for superconductors having long exposure to air. For the particular superconductor tested, bulk $YBa_2Cu_3O_7$ the sample was etched to a depth of 20 to 50 nanometers at 1.25 kV rms in 3-Pa argon for about 3 minutes. A 1- to 6-micrometers-thick contact pad was immediately sputtered onto the surface (4.2 kV rms, no applied bias), also under an argon atmosphere. The superconductor temperature was held to less than 100 degrees Celsius with a water-cooled sample holder.

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NASA Tech Brief
National Aeronautics and Space Administration
Goddard Space Flight Center, Greenbelt, Maryland

Licensing Opportunity

Distress Transmitter and Receiver

Identifying distress signals are sent and received automatically.

A radio transmitter and receiver are designed to be used together for the location and identification of persons, aircraft, or ships in distress. The modulation of the transmitted signal is characterized by a unique combination of frequencies, repetition rates, and duty cycles, so that the type or identity of the vehicle or person in distress can be ascertained from the signal. The receiver can be operated manually and monitored aurally in the conventional manner, but also includes automatic tuning and monitoring features to assist the operator in measuring the modulation characteristics and in detecting weak signals.

In the transmitter (see Figure 1) an oscillator generates a carrier signal at a frequency of 121.5 MHz. The carrier is fed to an output amplifier through a gate, which is opened or closed repeatedly to obtain full carrier, zero carrier, or 100-percent amplitude modulation. Because the output amplifier is nonlinear, it feeds the gated signal to the antenna at the two international distress frequences of 121.5 and 243 MHz.

Under the control of an electronic switch, the gate is opened or closed by a combination of timing pulses, by fixed-frequency audio oscillations, and by the output of a multivibrator, the frequency of which is repeatedly swept downward in the range of 1,600 to 300 Hz, 2 to 4 times per second (the present standard international distress signal). For example, a modulation scheme might call for a period (e.g., 0.5 s) of unmodulated carrier, followed by a period of the international distress signal, followed by a period of steady 200-Hz tone, and then by a repetition of the foregoing sequence.

In addition to the standard superheterodyne input and audio output sections, the receiver (see Figure 2) includes narrowband audio filters connected to lamps. The filters are set to the frequencies of the steady audio tones of known transmitters, to give visual indications of the reception of signals from those transmitters.

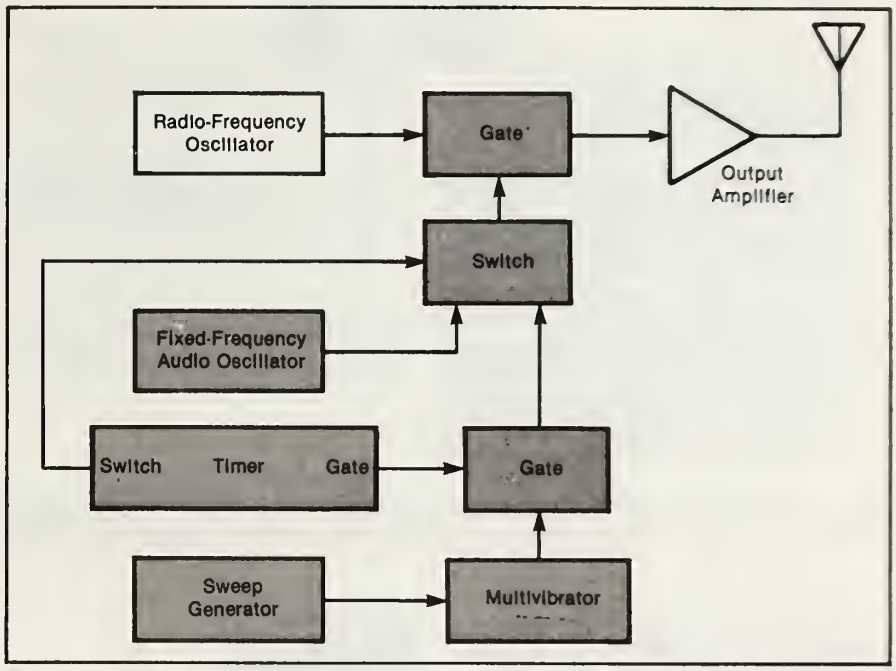

Figure 1. The **Transmitter** generates a signal characterized by a timed sequence of modulating pulses.

The receiver also includes a phase-lock loop that locks onto the carrier signal when it is unmodulated. Exploiting the fact that phase lock is lost during the modulation periods, the receiver is equipped with counters to measure the periods of lock and unlock. These periods are compared with stored values; if a match is found, the comparators cause lamps to light, thereby indicating that the signal is that of a known transmitter.

The output of the phase-lock loop is also fed to a frequency counter to assist the operator in identifying the signal source. The phase-lock loop repeatedly sweeps through a narrow frequency range until it locks on a signal. A timing circuit prevents the resumption of the sweep during the short modulation periods of the signal to which the receiver is locked. This feature prevents the receiver from attempting to lock onto other distress signals in the event that more than one is present. The phase-lock loop can also be unlocked and tuned manually.

A variable attenuator enables the operator to prevent false locking during the modulation period by adjusting the amplitude until the signal is below the loop threshold during modulation but above the threshold during no modulation. The correct adjustment of the attenuator is indicated by the repeated, regular flashing of the phase-lock-indicating lamp as the loop goes into and out of lock.

This work was done by Paul E. Wren of **Goddard Space Flight Center**.

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive

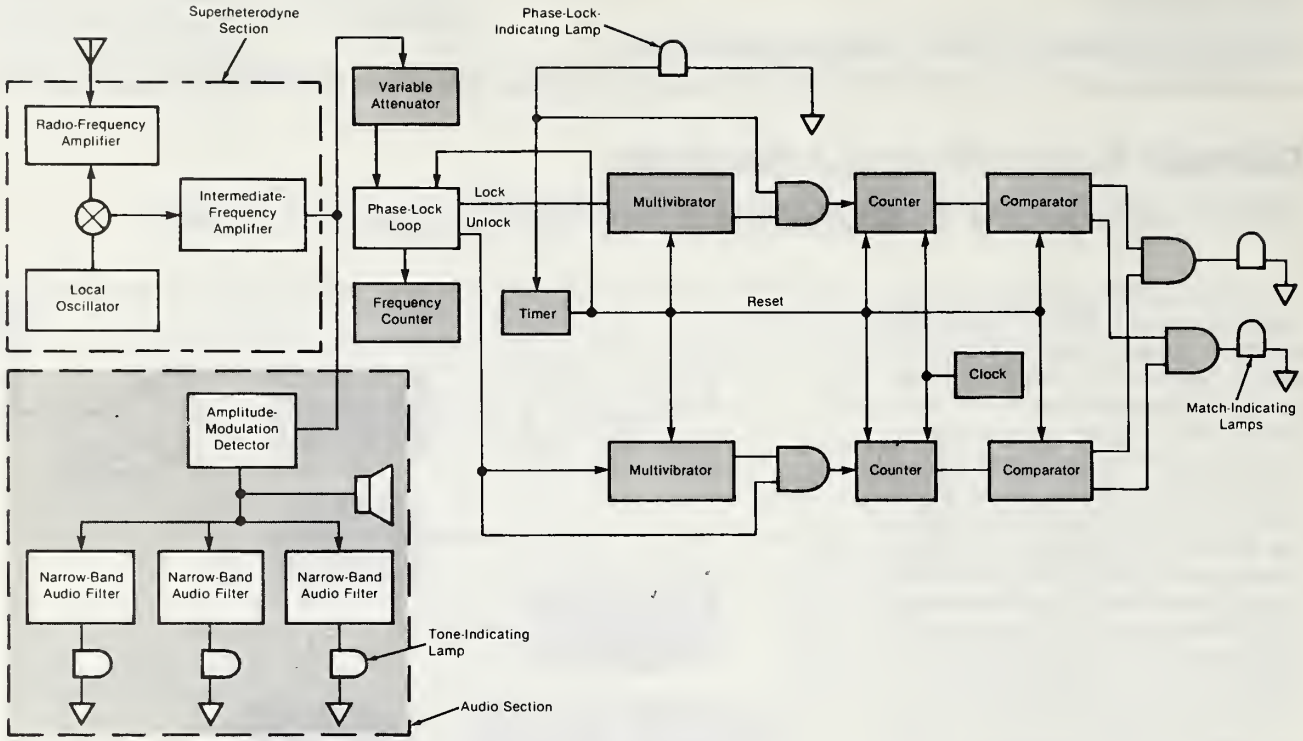

Figure 2. The **Receiver** automatically locks onto the signal and identifies it according to its modulation characteristics. The operator can also listen to the receiver and tune it manually. Together, the transmitter and receiver constitute a distress radio system.

license for its commercial development should be addressed to the Patent Counsel, Goddard Space Flight Center Refer to GSC-12821. /TN

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REFER TO THE NUMBER LISTED AT THE END OF THIS ARTICLE

NASA Tech Brief
National Aeronautics and Space Administration
NASA's Jet Propulsion Laboratory, Pasadena, California

Extension of Subreflector Increases Antenna Efficiency

The subreflector is widened up to about 1 wavelength beyond the optical limit.

According to calculations, the efficiency of an offset Cassegrain reflector antenna can be increased by about 8 percent by extending the edge of the subreflector outward about 1 wavelength beyond the optical limit. Even though the main reflector may then be partially shadowed by the subreflector, the partial aperture blockage is more than offset by the consequent reduction of diffraction on the subreflector. Similar conclusions apply to symmetric Cassegrain antennas.

The analysis was based on a parabolic main reflector with a hyperbolic subreflector (see Figure 1). In a typical prior design, the subreflector was placed so that its rim just touched the imaginary cylinder extending parallel to the optical axis from the rim of the main reflector; thus, by geometrical optics, the subreflector was an optical-limit subreflector.

The aperture efficiency of the antenna is the product of the spillover, illumination, polarization, and subreflector-diffraction efficiencies. These quantities were evaluated, using the geometric theory of diffraction to calculate the field scattered from the subreflector, and physical optics with the aid of the Jacobi-Bessel expansion to calculate the far field of the main reflector. To provide a comparison to show the effect of edge diffraction at the subreflector, the aperture efficiency was also calculated using geometrical optical scattering from the subreflector, with no subreflector edge diffraction included.

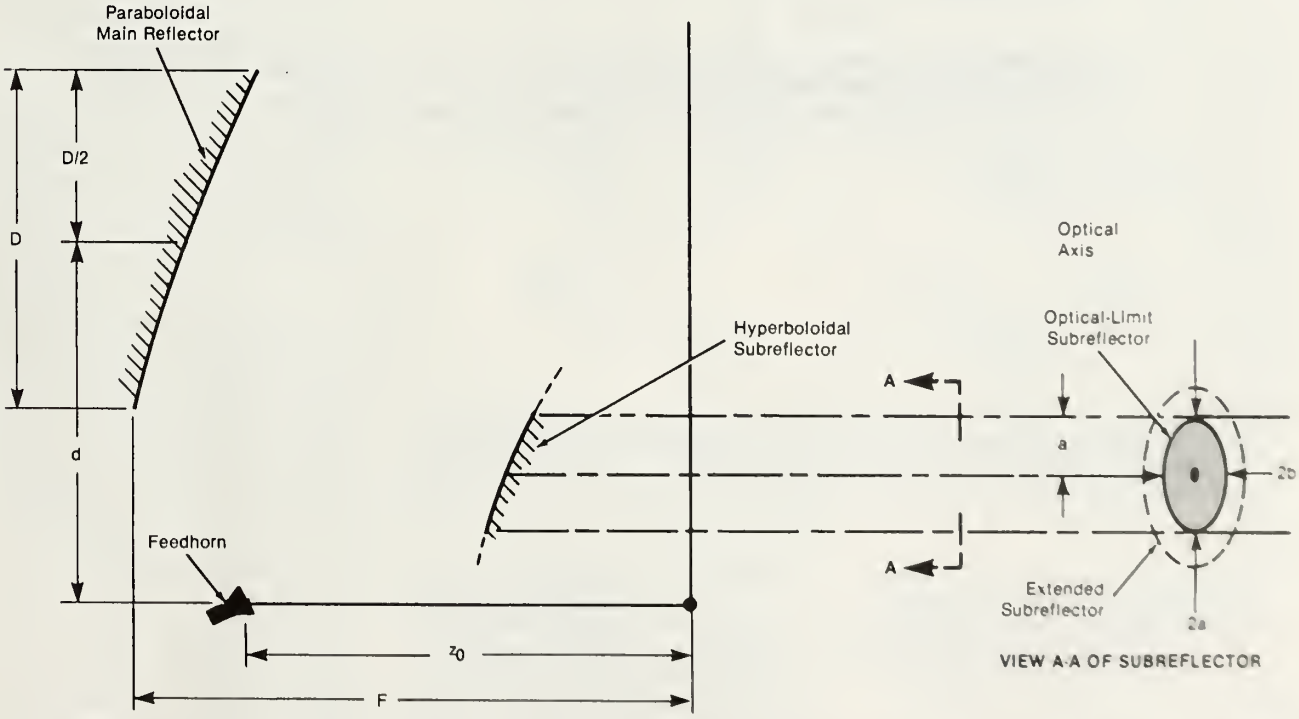


Figure 1. The **Offset Subreflector** is extended beyond the geometrical optical limit by extending the hyperbolic surface until it meets an elliptical cylinder that is parallel to the optical axis and has major axes larger than 2a and 2b, respectively.

The analysis was conducted parametrically using various subreflector extensions and subreflector illumination tapers. Figure 2 shows the result of a representative case. Because significant improvements are not achieved by extensions beyond 1 wavelength, plots are not shown for those cases. (The dotted curve shows the limiting case for which no subreflector diffraction was included.)

This work was done by Y. Rahmat-Samii of Caltech for **NASA's Jet Propulsion Laboratory**. *NPO-16872 /TN*

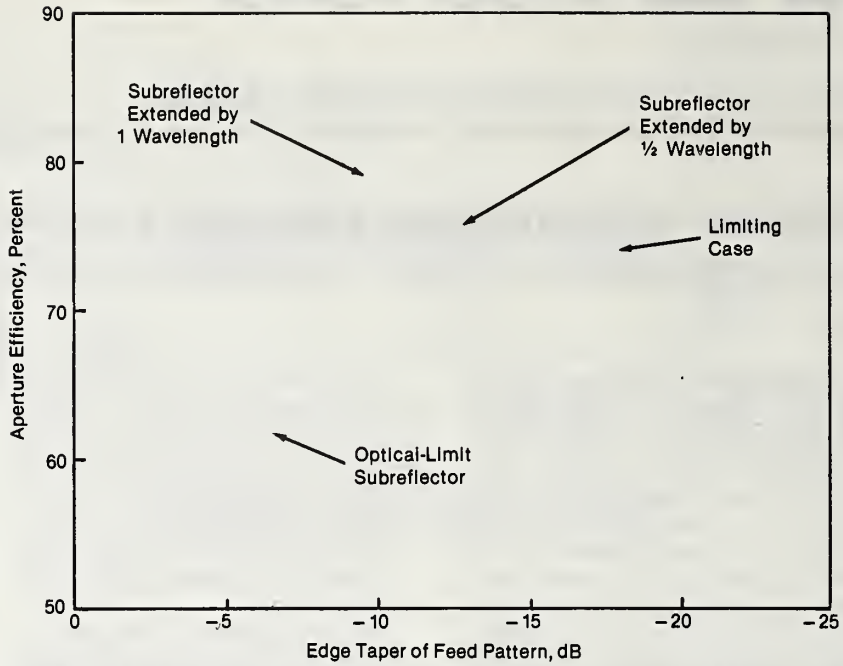


Figure 2. The **Aperture Efficiencies** for an antenna with an extended subreflector were calculated for various illumination tapers and two different subreflector extensions. Some of the antenna dimensions are $D = 100\lambda$, $a = 7.40\lambda$, $b = 6.08\lambda$, $d = 70\lambda$, $F = 96\lambda$, and $z_0 = 25\lambda$ (where $\lambda = 1$ wavelength).

FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD 21240; (301) 621-0100 Ext. 241*

REFER TO THE NUMBER LISTED AT THE END OF THIS ARTICLE

NASA Tech Brief
National Aeronautics and Space Administration
NASA's Jet Propulsion Laboratory, Pasadena, California

Cavity-Modulation Autotuner for Hydrogen Maser

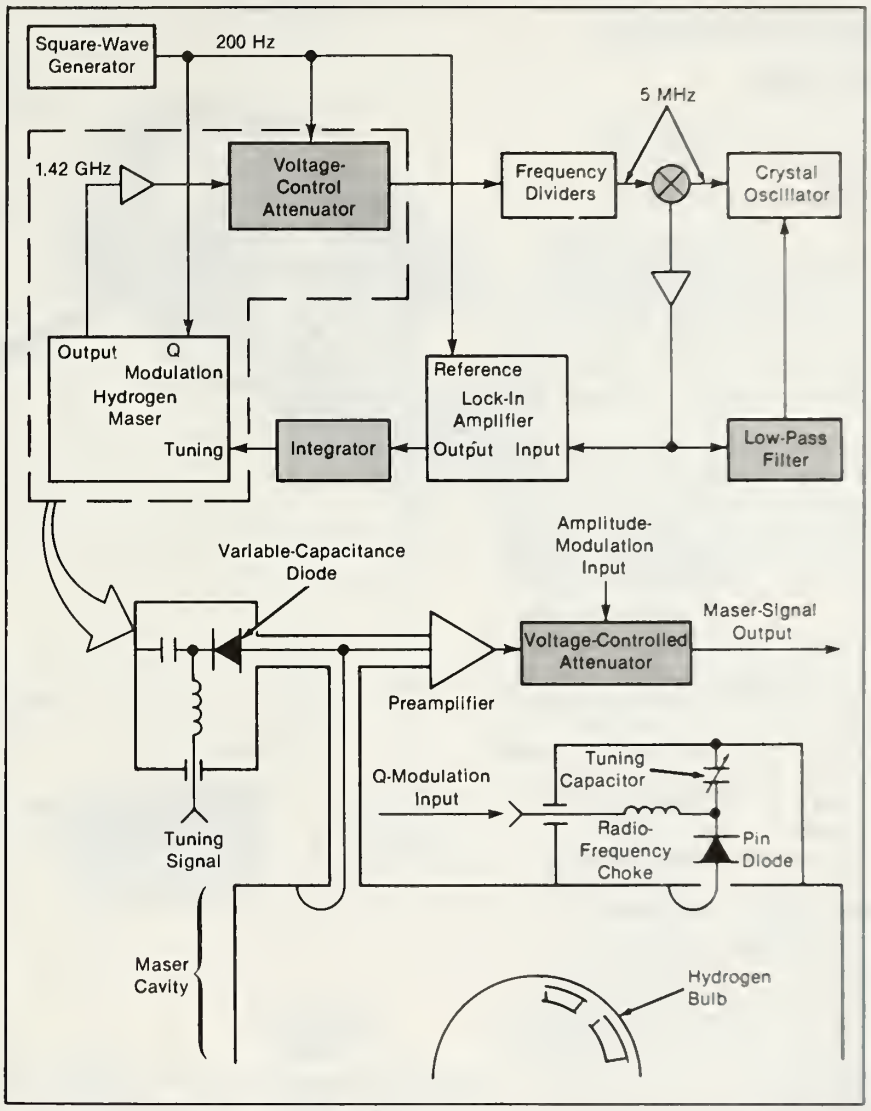
Resonance is maintained without incidental frequency modulation.

A cavity-modulation tuning system maintains the resonance of a hydrogen-maser cavity automatically, thereby stabilizing the maser frequency, without introducing the undesirable frequency modulation caused by other tuning systems. As its name implies, the system tunes the maser cavity rapidly by modulating one of the physical characteristics of the cavity that affect the resonant frequency. According to calculations, the long-term frequency stability of a maser equipped with the autotuner could be as good as $3 \times 10^{-13} \tau - ½$ (where τ is the observation time in seconds).

In cavity-modulation autotuning, a phase or amplitude modulation is caused by, and is proportional to, a deliberate periodic mistuning, in which the cavity resonance is dithered about a nominal adjustment point. The modulation is detected by a phase-sensitive amplifier, the output of which is used to derive a slow modulation (tuning signal) that corrects the frequency error of the adjustment point.

The modulator portion of the tuner is made of a few electronic components mounted on the maser cavity (see figure). The dithering signal — a 200-Hz square wave — is applied to a positive/intrinsic/negative (PIN) diode. The tuning signal is applied to a variable-capacitance diode.

By a suitable choice of the parameters of the PIN diode and the components with which it is mounted and coupled to the cavity, the effective diode-circuit capacitance can be made to remain constant when the current through the diode is varied. In that case, the diode-resistance variation due to the modulating signal affects only the ratio of reactance to resistance (Q) of the circuit. Although the Q of the maser and, therefore, the phase of the maser output are modulated, the frequency of the maser output remains the same. The circuit can therefore be operated in a low-Q condition without adversely affecting the frequency stability.



The **Frequency-Controlling Components** of the tuning system are placed at the maser cavity, within the maser vacuum. The thermal environment is well controlled, and the device is insensitive to the driving signal: these features contribute to the stability of the maser frequency.

In experiments, the tuner compensated for variations in the maser-cavity frequency with a loop gain greater than 1,000. Amplitude modulation incidental to the Q modulation was also compensated by applying the 200-Hz square wave to a voltage-controlled attenuator. The tuner should be of interest to those concerned with precise measurements of time and frequency.

This work was done by G. J. Dick and T. K. Tucker of Caltech for **NASA's Jet Propulsion Laboratory**. *NPO-16906 /TN*

FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD 21240; (301) 621-0100 Ext. 241*

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NASA Tech Brief
National Aeronautics and Space Administration
Marshall Space Flight Center, Alabama

Licensing Opportunity

Reliable Wiring Harness

Materials and design are changed for immunity to vibration and corrosion.

A new harness for electrical wiring includes plugs that do not loosen from vibration. In addition, the ground braids are prevented from detaching from connectors and are constrained so that the braids do not open into swollen "birdcage" sections.

To prevent loosening, self-locking connectors (see figure) are used. Even if they are screwed on one turn loose, the connectors tighten under vibration. The connectors are made of stainless steel instead of the corrosion-prone aluminum used previously.

The ground braid is held securely by a ring of stainless-steel spring. The resistance of the ground-braid termination is low enough to protect the cable from lightning. A boot sheathing the cable prevents the "birdcages" from forming. A removable back shell provides access for maintenance.

This work was done by Kenneth C. Gaspar of Rockwell International Corp. for **Marshall Space Flight Center**. *No further documentation is available.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center Refer to MFS-29192/TN

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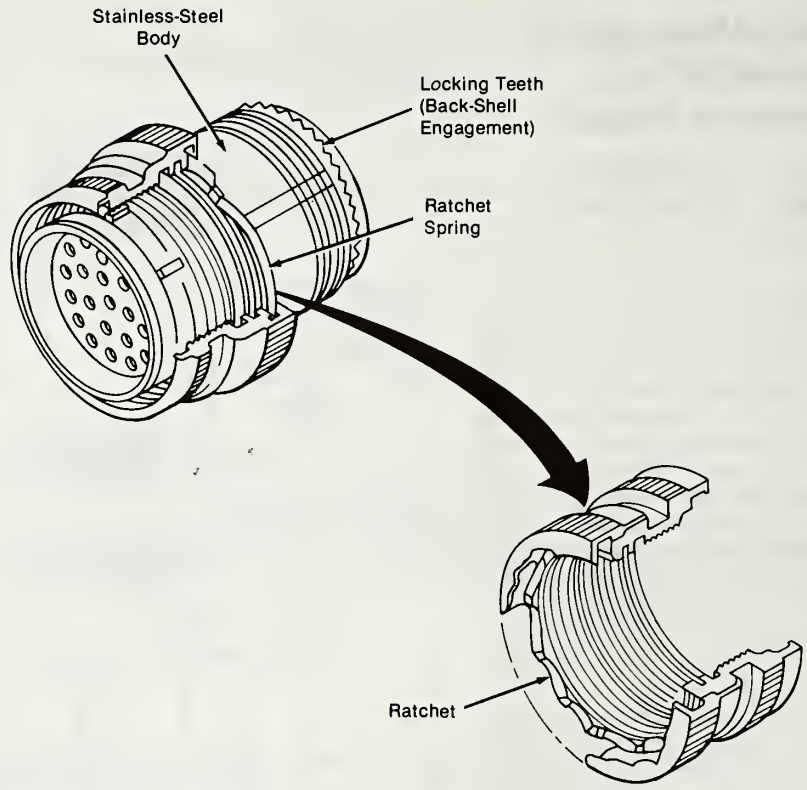
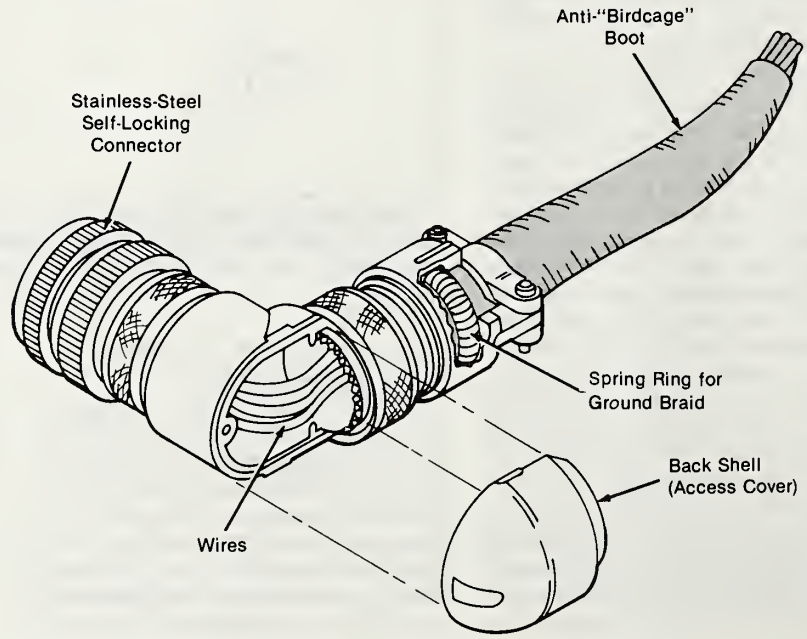


SELF-LOCKING-CONNECTOR VIEW ROTATED 180°



ANTI-"BIRDCAGE" HARNESS

A **Spring of Stainless Steel Encircles** the ground braid. The self-locking connector contains a ratchet that not only prevents the connector from opening, but tightens when it is vibrated.

FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD 21240; (301) 621-0100 Ext. 241*

REFER TO THE NUMBER LISTED AT THE END OF THIS ARTICLE

NASA Tech Brief
National Aeronautics and Space Administration
Goddard Space Flight Center, Greenbelt, Maryland

Licensing Opportunity

Self-Identifying Emergency Radio Beacons

Rescue teams are aided by knowledge of the vehicle in distress.

An emergency radio transmitter gives information about the identity and/or type of vehicle in distress. Thus, it not only guides rescue workers to a downed airplane or sinking ship but also alerts them to the approximate number of people to be rescued and the nature of the rescue operation. It is similar to conventional emergency transmitters except that it contains additional timing and modulating circuits.

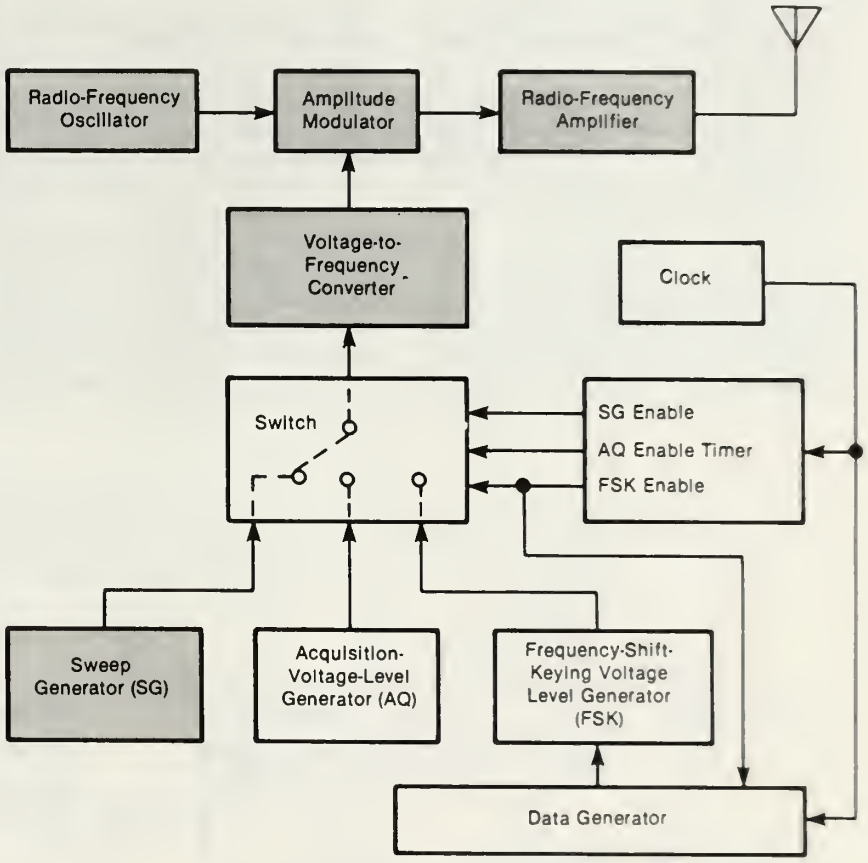
In the transmitter (see figure), a radio-frequency (RF) oscillator produces the 121.5-MHz sinusoidal carrier signal assigned by the FCC. The transmitter also contains a voltage-to-frequency converter with a range of 0 to 1,600 Hz. An amplitude modulator impresses the sinusoidal output of the voltage-to-frequency converter on the carrier, producing an amplitude-modulated RF signal. A nonlinear RF amplifier boosts the modulated carrier signal, providing a frequency-doubled output at 243 MHz as well as an amplified 121.5-MHz output.

Under control of a timer and switch, the transmitter broadcasts three signals in a predetermined sequence:

1. An RF carrier amplitude-modulated at a typical frequency of 100 Hz serves as acquisition signal. When an Earthbound or orbiting station receives this tone, it recognizes that an information signal will follow and prepares to receive it. To produce the acquisition signal, the switch connects an acquisition-voltage-level generator to the voltage-to-frequency converter.
2. An RF carrier is amplitude-modulated by a series of tones of two distinct frequencies, typically 150 and 250 Hz. The lower frequency tone represents binary "zero," while the higher frequency tone represents binary "one." The sequence of zeros and ones provides a unique code that identifies the transmitter and its vehicle to the rescuers.
3. A conventional RF carrier is amplitude-modulated by a tone that repeatedly descends from about 1,600 to 800 Hz. This is the conventional distress signal, and when demodulated by the rescuers' receiver, it sounds like a siren. The switch connects a sweep generator to the voltage-to-frequency converter to produce this signal.

The pattern of binary zeros and ones from the data generator may be the identification number of the vessel or aircraft. A 30-to 128-bit field is adequate for this type of identification and can convey such additional information as the type of emergency and the latitude and longitude. A low pulse repetition rate — on the order of 32 pulses per second — ensures accurate transmission without error-correcting codes.

To produce the identifying signal, a frequency-shift-keying voltage-level generator generates two distinct voltages in direct response to the voltages of the binary outputs of a data generator. One voltage sets the output of the voltage-to-frequency converter to 150 Hz, and the other, to 250 Hz. The frequencies are sufficiently different from the acquisition signal and the conventional distress signal to ensure reliable demodulation.



Additions to a Standard Emergency Transmitter, depicted in color, enable the transmitter to send rescuers an identifying signal in addition to the conventional distress signal created by the sweep generator. The data generator contains the identifying code.

The conventional sirenlike distress signal should last fairly long to maximize the probability of its detection by local aircraft and search parties. The acquisition signal merely indicates that an identification signal is coming; both the acquisition and data signals can be short. For 128 bits transmitted at 32 bits per second, the identification signal would last 4 seconds. The acquisition signal would be of equal duration. The siren signal would last 52 seconds, giving a 1-minute cycle.

This work was done by Morton L. Friedman of **Goddard Space Flight Center**.

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Goddard Space Flight Center Refer to GSC-13089 /TN

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REFER TO THE NUMBER LISTED AT THE END OF THIS ARTICLE

NASA Tech Brief
National Aeronautics and Space Administration
Langley Research Center, Hampton, Virginia

Licensing Opportunity

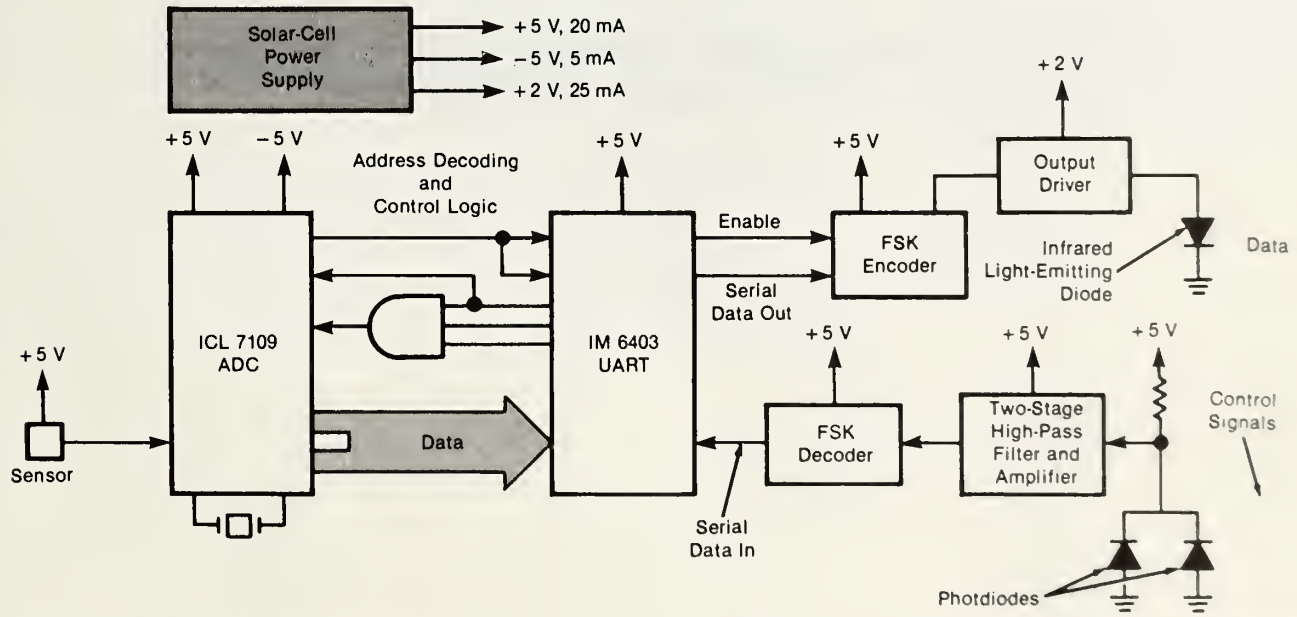
Solar-Powered Sensor Module

A hybrid sensor module with no external electrical interconnections includes an optical data link.

Geo-orbital systems of the near future will require more-sophisticated monitoring and control systems than do current satellite systems, with an emphasis on the electronic density and autonomy of the subsystem components. Hybrids that have typically served as components in spacecraft electronics will have to assume the roles of subsystems and systems. A solar-powered hybrid sensor module (see figure) has been designed to combine low-power CMOS electronics, GaAs solar cells, a crystal oscillator, standard universal asynchronous receiver/transmitter (UART) data format, and a bidirectional optical data link into a single 1.25- by 1.25- by 0.25-in. (3.18- by 3.18- by 0.64-cm) hybrid package that has no need for electrical input or output. Sensor modules with optical data links could also be useful on Earth in hazardous environments; for example, in explosive atmospheres or high-voltage equipment.

The module is made up of four general subsystems: (1) the power supply, (2) the data-acquisition section, (3) the control section, and (4) the communication section. The power supply is an array of solar cells attached to the hybrid package. The data-acquisition section includes the sensors or transducers and the analog-to-digital converter (ADC). The control section coordinates the functions of the other sections. The communication section receives and transmits information and forms the link between the control computer and any remote sensors under its control.

Data are transmitted serially over a bidirectional optical data link that offers the option of operation without wires or cables connecting the data source to the receiver. In addition, the optical data transmission is



The **Hybrid Sensor Module** measures such parameters as temperature, acceleration, and strain. The module transmits measurement data to a central unit and receives control signals via light beams.

considered preferable to more-conventional radio-frequency or microwave transmission systems because it will not interfere with the spacecraft electronics. The modulation method chosen for this application was frequency-shift keying (FSK) because of its high immunity to noise.

Three self-contained solar-powered hybrid sensor modules that were built and tested met the design goals of minimal module weight and no electrical interconnections. For the most part, standard fabrication processes were used. Nonstandard techniques that were developed were compatible with standard hybrid processing. The hybrid module functioned to a large extent as a separate system, and the use of a free-space optical data link between the hybrid and the controlling computer was successfully demonstrated. Initial results are very promising, and the potential applications of such a system, from data gathering to systems control, are numerous.

This work was done by J. Michael Johnson of Hughes Aircraft Co. for **Langley Research Center**.

11343/NSP], "Solar Powered Hybrid Sensor Module Program."

Copies may be purchased from the National Technical Information Service, Springfield, Virginia 22161, [A03]

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Langley Research Center Refer to LAR-13454 /TN

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REFER TO THE NUMBER LISTED AT THE END OF THIS ARTICLE

NASA Tech Brief
National Aeronautics and
Space Administration
Lewis Research Center, Cleveland, Ohio

Variable-Speed, Constant-Frequency Generation of Power

Feedback of the stator power and reactive volt-amperes determines the rotor excitation.

A doubly-fed, wound-rotor generator can be used to provide a constant stator power, reactive volt-amperes, and frequency while the shaft speed varies. To accomplish this, it is necessary to control the rotor excitation; namely, the frequency, amplitude, and phase of the rotor current.

A prior method for accomplishing this type of operation has been to use a rotor excitation based on shaft speed. The disadvantage of this method is that, while the speed is adequate for the determination of the slip frequency, it is not adequate for the control of the power and of the reactive volt-amperes. When the speed is used as the controlling parameter, the rotor excitation lags the changes in the stator load. The fluctuations in the power and reactive volt-amperes in the stator are directly related to angular disturbances in the shaft.

The new method involves a control circuit that separates the rotor excitation into the generation of the slip frequency and the control of the amplitude and phase. In this control circuit, the speed determines the slip frequency, while the stator power and the reactive volt-amperes determine the amplitude and phase of the rotor current.

Small angular disturbances of the shaft produce changes of phase in the induced stator voltage, causing large fluctuations in the stator power and reactive volt-amperes. To prevent this, the rotor-control circuit must respond quickly enough to change the phase of the rotor current. When the proper proportions of stator power and reactive volt-amperes are fed back to the rotor-control circuit to control the phase, the desired excitation is obtained.

This work was done by Frank J. Brady of **Lewis Research Center**. *No further documentation is available.*
LEW-14054 /TN

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REFER TO THE NUMBER LISTED AT THE END OF THE ARTICLE

Calculating Electromagnetic Fields of a Loop Antenna

Approximate field values are computed rapidly.

The MODEL computer program was developed to calculate the electromagnetic-field values of a large loop antenna at all distances to an observation point. The antenna is assumed to be in an x-y plane with its center at the origin of the coordinate system. MODEL calculates the field values in both rectangular and spherical components. It also solves for the wave impedance.

MODEL is not intended to give extremely accurate answers but to give acceptable answers very quickly. MODEL has been used to investigate the electromagnetic fields the Space Shuttle may encounter from some of the planned payloads that will emit low-frequency radiation. The program is a simple and fairly accurate tool for finding approximate field values in the near field of a large loop antenna.

MODEL is a quick interactive program. The user is prompted for the radius of the loop antenna, the starting frequency, the stopping frequency, the change in frequency, and information on the observation point. The output includes the coordinates of the observation point, the frequency, magnetic-field values, electric-field values, and the wave impedance.

MODEL is written in MicroSoft FORTRAN 77 for interactive execution and has been implemented on an IBM PC with a memory requirement of approximately 120K of 8-bit bytes. MODEL was developed in 1985.

This program was written by Mitchell B. Schieffer of McDonnell Douglas Corp. for **Johnson Space Center**.

MSC-21110 /TN

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NASA Tech Brief
National Aeronautics and Space Administration

Computing Radiation Characteristics of Phased Arrays

Radiated powers, directivities, and radiation patterns can be calculated.

One of the most important radiation characteristics of an antenna system is the directivity. The accurate determination of this parameter is essential for the analysis and design of advanced antenna systems. In general, for most-commonly-used array elements like open-ended waveguides, horns, or microstrip patch antennas, an analytical expression of the $(\cos \theta)^q$ type can be used to tailor actual element patterns properly. Experimentally-measured element patterns could include mutual coupling, which may be significant in large arrays. Expressions for the directivity and radiation pattern of a single element and of a rectangular array using $(\cos \theta)^q$-type element patterns have been reported.

With the advent of monolithic microwave integrated circuits, phased arrays have become key components in the design of advanced antenna systems. Array-fed antennas are used extensively in today's multiple-beam satellite antennas.

A computer program was devised to generalize these results and obtain an efficient numerical technique for computing the directivity and the radiation pattern of the generalized array. The characteristics of the generalized array used in this program include arbitrary element locations; element patterns that are of the $(\cos \theta)^q$ type, analytically describable by other functions, or experimentally measured; and the polarizations and excitations of the elements.

The computer program is based on a very efficient numerical technique for calculating the radiated power (Romberg integration), directivity, and radiation pattern of a phased array. The formulation is very general and takes into account arbitrary element polarization, electric-field-plane and magnetic-field-plane element pattern, element location, and complex element excitation.

One of the advantages of this generalized array formulation is that it does not break down in special cases as might other approximations that use closed forms. Also, the formulation does not limit the observation of the pattern to the far-field zone. This can be very useful if the generalized formulation is going to be used with analysis programs for dual-reflector configurations. The program can be modified easily for use in the analysis of reflectors with phased-array feeds.

This computer program is one of the principal research tools at NASA Lewis Research Center for the analysis of advanced space-communication antenna systems. The generalized formulation and computer program provide complete flexibility in the analysis of array configurations and in the accurate analysis of experimental data. The program is written in FORTRAN IV and can be used on an IBM 370 computer.

This program was written by Roberto J. Acosta of **Lewis Research Center**.

LEW-14460 /TN

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Designing Digital Filters

A computer program calculates a performance index from magnitude and phase errors.

The Digital Filter Design program presents a method to compare desired and designed digital filters by minimizing the sum-square error of the differences in magnitude and phase angles. Most filter-design techniques emphasize magnitude characteristics. Such techniques are adequate for a control system in which the phase angle of a filter imposes minor effects on the stability of the system. However, in a closed-loop feedback control system, a designed filter that introduces an excessive phase angle may distort the signal or push the system to instability. This Digital Filter Design program has been used to reshape the Space Shuttle pitch body-bending filter to provide more attenuation to flexible-vehicle-resonance modes without sacrificing the rigid-vehicle performance.

This program uses the Fletcher-Powell unconstrained-minimization method to calculate a performance index from the magnitude and phase errors. This index can then be used to measure the goodness of various filter designs. The input includes the number of second-order cascade sections in the designed filter, available frequency data points with desired phases and magnitudes, weighting factors for phases and magnitudes, initial estimates of filter coefficients and gain, and system sampling time. Subroutines are provided for printing and simple plotting of the response of the designed filter as a function of frequency.

This program is written in FORTRAN IV for batch execution and has been implemented on a CDC CYBER 830 computer operating under NOS with a central-memory requirement of approximately 76K (octal) of 60-bit words. The program was developed in 1983.

This program was written by Chiang Lin of McDonnell Douglas Corp. for **Johnson Space Center**. *MSC-20982 /TN*

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NASA Tech Brief
National Aeronautics and Space Administration

Designing Rectangular RHCP Microstrip Antennas

A program calculates the configuration and the impedance.

RHCP, the Right-Handed, Circularly Polarized Microstrip Antenna program, aids in the design of a rectangular microstrip-antenna element, given the desired frequency of operation and characteristics of the substrate. RHCP begins the design calculations on the basis of a square element with linear polarization. The effective dielectric constant and changes in electrical length due to fringing at the edges of the radiating element are taken into account. A coaxial feed is inset with 50 ohms input impedance. By placement of the feed such that two orthonormal modes are produced in the antenna cavity, right- or left-handed circular polarization is obtained.

The input to RHCP consists of the desired frequency, the dielectric constant, and the thickness of the substrate. The output consists of the final rectangular configuration, the proposed placement of the feed inset, and the actual input impedance.

RHCP has been used successfully for frequencies between 2 and 15 GHz for thin substrates. This program was used to design antenna elements for the S-band quad antennas on board the Space Shuttle and is a part of the design project for the S-band phased-array-antenna radiating aperture.

RHCP is written in FORTRAN 77 for interactive execution and has been implemented on a DEC VAX-series computer operating under VMS. The program was developed in 1985.

This program was written by Shayla E. Davidson of **Johnson Space Center**.
MSC-21180 /TN

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Locating Spaceborne SAR Imagery

An arbitrary picture element can be located precisely.

The TLOCATE computer program was developed to determine the precise location of an arbitrary picture element (pixel) in a digital synthetic-aperture-radar (SAR) image. The approach requires no standard ground reference point and is independent of the attitude of the spacecraft. Traditional preprocessing of raw data into digital images may result in geometrically distorted pictures. TLOCATE will aid in unsupervised geometric rectification, location of pixels, and the combination of multiple image frames into mosaics. Locations predicted by TLOCATE using SEASAT and SIR-B images have been compared to high-precision topographical maps with an accuracy of approximately 200 m.

The location of a pixel in a digital image is determined by the intersection of the centroid plane of the radar beam and the surface of the planet. TLOCATE represents the intersection with (a) a model of the shape of the Earth, (b) the SAR Doppler equation that defines the plane of the radar centroid, and (c) the SAR range equation, which includes both signal-transmission properties and the rotation of the Earth.

TLOCATE can perform three major procedures: (1) determine latitude and longitude of the requested target pixel; (2) estimate such Doppler parameters as the centroid and the rate of change of frequency at the four corners of the image, the radius of the Earth, and the slant range; and (3) generate such postprocessing parameters as the swath velocity, the number of pixels to be deskewed, the center incidence angle, and the latitude and longitude of the four corners. These algorithms require the input of precise spacecraft ephemeris data (position and velocity) and operating characteristics of the SAR sensor.

TLOCATE is written in FORTRAN 77 for batch or real-time execution and has been implemented on a DEC VAX 11/785 computer operating under VMS 4.1 with a central-memory requirement of approximately 34K of 8-bit bytes. The program was developed in 1985.

This program was written by J. C. Curlander and S. Pang of Caltech for **NASA's Jet Propulsion Laboratory**.
NPO-16861 /TN

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NASA Tech Brief
National Aeronautics and Space Administration

PCACE — Personal-Computer-Aided Cabling Engineering

Routine aspects of the design of wiring harnesses are automated.

The PCACE computer program has been developed to provide an inexpensive, interactive system for learning and using an engineering approach to interconnection systems. PCACE is basically a database system that stores information as files of individual connectors and handles wiring information in circuit groups stored as records. This directly emulates the typical manual engineering methods of handling data, thus making the interface between the user and the program very natural.

Data files can be created, viewed, manipulated, or printed in real time. The printed output is in a form ready for use by fabrication and engineering personnel. PCACE also contains a wide variety of error-checking routines, including checks of connector contacts during printing.

The user can edit existing files of data on wiring harnesses or create new files. In creating a new file, the user is given the opportunity to insert all the connector and harness "boilerplate" data that would be part of a normal connector wiring diagram. These data include connector reference designator, connector part number, backshell part number, cable reference designator, cable part number, drawing revision, relevant notes, standard wire gauge (in the Apple version only), and maximum circuit count. Any item except the maximum circuit count may be left blank, and any item may be changed later.

Once a file is created and organized, the user is directed to the main menu and has access to the file boilerplate, the circuit-wiring records, and the wiring-records index list. The organization of a file is such that record zero contains the connector/cable boilerplate, and all other records contain circuit-wiring data.

Each wiring record handles a circuit with as many as nine wires in the interface. The record stores the circuit name and wire count and the following data for each wire: wire identifier, contact, splice, wire gauge, wire/group type, wire destination, and note number. The PCACE record structure provides for a wide variety of wiring forms using splices and shields, yet retains sufficient structure to maintain ease of use.

PCACE is available in two versions. The Apple version is written in P-Code Pascal and has been implemented on an Apple II computer with a memory of 64K of 8-bit bytes, two 5¼-inch floppy-disk drives, and an Epson MX-series printer. It was developed in 1983. The IBM PC version of PCACE is written in TURBO Pascal 3.0 and has been implemented on IBM PC, XT, and AT systems under DOS 3.1 with a memory of 512K of 8-bit bytes, two floppy-disk drives, an RGB monitor, and a printer with ASCII control characters. The IBM PCACE was developed in 1986.

This program was written by Joseph W. Billitti of Caltech for **NASA's Jet Propulsion Laboratory**. *NPO-17006 /TN*

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Energy

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370 Compact Sun-Position Sensor — A single device finds and tracks the sun. (Licensing Opportunity)

Department of Energy

Technology Application

Solar Energy Research Institute

Simple Model Computes Spectral Solar Radiation

Background

The spectral distribution of radiation (the intensity of sunlight at different wavelengths) at the earth's surface varies with atmospheric conditions. This variation is important to photovoltaic (PV) applications because each type of PV device works best for a selected range of wavelengths. A spectroradiometer can measure the sun's spectrum directly. But it is difficult to calibrate and expensive to buy. Alternatively, researchers use standard atmospheric measurements and a computer model to calculate the spectrum.

Some computer models picture the atmosphere as many separate layers. By rigorously applying mathematics of radiative transfer, these models are used to predict what happens to sunlight as it filters through the atmosphere. But these rigorous models need large, expensive computers.

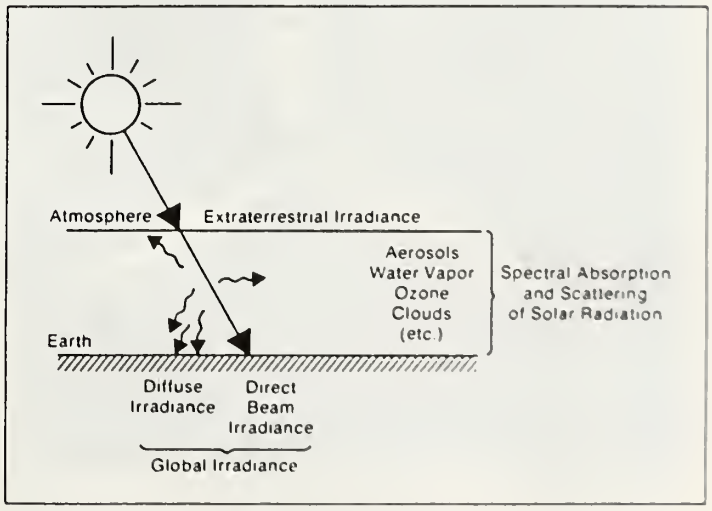
Accomplishments

Now researchers at the Solar Energy Research Institute (SERI) have developed a simple model to accurately calculate the sun's spectrum using an inexpensive microcomputer. The model, called SPCTRAL2, calculates both direct beam irradiance (sunlight that is transmitted directly to the earth's surface) and diffuse irradiance (sunlight that is scattered out of the direct beam but reaches the earth's surface). As an added feature, the model also predicts the spectrum that reaches either horizontal or tilted surfaces. The SERI model uses new empirical coefficients determined by comparisons with rigorous models and measured spectra.

Calculating the direct beam component starts with a baseline spectrum of sunlight before it reaches the atmosphere. Then the model adjusts this extraterrestrial spectrum for the distance between the earth and sun, the transmittance after scattering by gaseous molecules and aerosols in the air, and the transmittance after absorption by ozone and water vapor. Calculating the diffuse component is more complex. The model sums three sources of diffuse sunlight: radiation scattered by gaseous molecules; radiation scattered by aerosols; and radiation resulting from multiple scattering between the air and the ground.

To calculate these components, several parameters go into the model: the solar elevation angle (angle of the sun above the horizon), atmospheric turbidity (haziness); amount of water vapor, amount of ozone, barometric pressure, and the day of the year.

Calculating the total (global) irradiance on an inclined surface

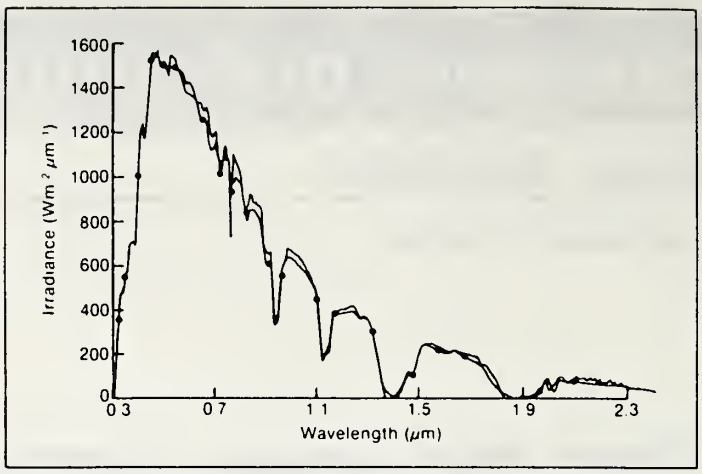


How the atmosphere affects solar radiation

requires knowing the direct beam and diffuse irradiances on a horizontal surface, the tilt angle of the inclined surface, and the incidence angle of the direct beam on the inclined surface. Researchers tested three published algorithms for inclined surfaces and chose one that gave the best agreement with rigorous modeled data.

Benefits

The new simple model has given good agreement with both rigorously modeled data and measured data. With a few common meteorological measurements, scientists can now use inexpensive microcomputers to model and optimize the performance of photovoltaic devices that are sensitive to the sun's spectrum.



Comparison between global radiation measured on a tilted surface at Golden, Colorado, and modeled data using SPCTRAL2. The closeness of the two lines shows the close fit between the modeled and measured data.

Additional Information

Publications

Bird, R. E., and Riordan, C. J. "Simple Solar Spectral Model for Direct and Diffuse Irradiance on Horizontal and Tilted Planes at the Earth's Surface for Cloudless Atmospheres." *J. of Climate and Appl. Meteorology*, Vol. 25, No. 1, January 1986, 87-97.

Riordan, C. J. "Spectral Solar Irradiance Models and Data Sets." *Solar Cells*, 19 (1986) 223-232.

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SERI/SP-260-2734/R-2

Solar Energy Research Institute

Computer Software

PROPSH Performance Code for Horizontal-Axis Wind Turbines

Background

The cost of power generated by wind turbines can be reduced by improving performance. One way to do this is to design more efficient rotors with improved blade geometry and airfoils that can operate on higher towers. To study the effect that such design changes have on performance, researchers often use specialized computer programs called codes.

Conventional performance prediction codes are often inaccurate because they exclude several realistic operating conditions. For example, horizontal-axis wind turbines are usually designed to face into the wind for maximum power output. But experience shows that many free-yawing turbines (those with rotors that lack active yaw control) do not accurately track the wind. Inaccurate tracking can be caused by wind shear, by rotor shaft tilt, or by upwind disturbances from other machines.

In addition, conventional codes may have a difficult time evaluating turbine performance at high wind speeds. The inadequate theory on which these codes are based may cause errors of up to 40% when predicting peak power and blade load.

Accomplishments

Scientists at the Solar Energy Research Institute (SERI) have developed a computer code to better predict the performance of horizontal-axis wind turbines. The versatile code, called PROPSH, is available in Fortran-77 for use on personal computers.

PROPSH takes into account the effects of yaw and post-stall airfoil characteristics. It is based on AeroVironment's PROP, a code that calculates performance from input on two-dimensional airfoil characteristics at several points along the blade. PROPSH improves the usefulness of PROP in several ways: it can analyze up to 20 spanwise blade segments; it predicts machine performance even when the rotor shaft is tilted or the rotor does not directly face into the wind, and its output can be expressed in dimensional units as well as ratios.

PROPSH features two special subroutines that enhance its accuracy across a wide range of wind speeds. One subroutine uses the Glauert approximation to account for low wind speed in the presence of strong, self-induced wake interactions. At higher wind speed, the code uses

Researchers are using the PROPSH code to design improved second-generation blades for the retrofit market. These improved blades first will be used on the WestWind Phoenix, an American-built machine currently equipped with foreign blades.

another special subroutine to synthesize three-dimensional airfoil data even after stall has been reached. These important features produce a smooth data curve all the way up to the highest stall angle of attack experienced by each blade section.

Descriptive rotor parameters that can be entered into the program include the number of blades, blade geometry, blade radius, and the rotor's revolutions per minute. Users also can enter the number of blade segments desired for analysis, the pitch angle, airfoil performance characteristics, and wind characteristics.

The code produces tabulated output of rotor performance as a function of either tip speed ratio or advanced ratio (the ratio of tip speed to wind speed) for a given set of blade pitch angles. Efficiency for each value of tip speed or advanced ratio also is listed. The code will provide information on each blade segment, including axial and circumferential induction factors at the plane of the rotor, airfoil drag and lift coefficients, airflow angle, power coefficient, torque coefficient, and thrust coefficient. This information allows researchers to make detailed comparisons between differing wind turbine designs.

Most predictions obtained from PROPSH closely agree with the results of outdoor wind turbine tests. However, some recent experiments indicate that PROPSH may underpredict peak power by 3% to 15% due to additional effects resulting from blade rotation. SERI researchers will be collaborating with industry to resolve this discrepancy.

Benefits and Applications

Wind energy professionals can use the PROPSH code to better predict rotor performance. And because PROPSH can be run quickly and easily on a personal computer, it may allow faster development of more efficient horizontal-axis wind turbines.

Researchers at SERI now routinely use PROPSH to predict the power output of experimental wind machines. The code also has been commercialized and is widely used by companies such as Fayette Manufacturing and U.S. Windpower.

Additional Information

Publications

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SERI/SP-260-2734/W-2

NASA Tech Brief
National Aeronautics and Space Administration

Analyzing Solar-Power Options for Spacecraft

Costs, weights, and efficiencies are estimated.

The Solar Space Power Analysis Code, SOSPAC, was developed to examine the solar-thermal and photovoltaic power-generation options available for a satellite or spacecraft in low orbit around the Earth. SOSPAC is a software tool for the preliminary analysis of systems and enables the engineer to compare the areas, weights, and costs of several candidate electric- and thermal-power systems. The configurations studied include photovoltaic arrays and paraboloidal-dish systems to produce electricity only and in various combinations to provide both thermal and electric power.

SOSPAC has been used for comparison and parametric studies of proposed power systems for the NASA Space Station. The initial requirements are projected to be about 40 kW of electrical power and a similar amount of thermal power with temperatures above 1,000 °C. For objects in low orbits around the Earth, the aerodynamic drag caused by suitably-large photovoltaic arrays is substantial. Smaller paraboloidal dishes can provide thermal energy at a collection efficiency of about 80 percent but at increased cost.

SOSPAC enables an analysis of the cost and performance factors of five hybrid power-generating systems. The input includes electrical- and thermal-power requirements, durations of Sunlight and shade for the satellite, and the unit weights and costs of subsystems and components. The performance equations of the five configurations are derived, and the output tabulates the total weights of the power-plant assemblies, areas of the arrays, efficiencies, and costs.

SOSPAC is written in FORTRAN IV for batch execution and has been implemented on an IBM PC operating under DOS with a central-memory requirement of approximately 60K of 8-bit bytes. The program was developed in 1985.

This program was written by M. K. Selcuk of Caltech for **NASA's Jet Propulsion Laboratory**. *NPO-16855 /TN*

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Assessment of Advanced Concentrator Photovoltaic Modules

Many designs are analyzed in terms of cost and efficiency.

A computer program was developed to estimate probabilistically the total and component costs to end users of concentrating photovoltaic arrays in the 1990's. The program is based on a modified version of the SIMRAND program (SIMRAND — Simulation of Research and Development projects — is available separately from COSMIC) to estimate the total cost of a system for a large number of module designs. The module design that yields the minimum cost for the total system is then chosen as the preferred design. To obtain a distribution of expected module costs, a simulation is performed. The component estimates made by SIMRAND include the efficiency of a module and the costs of a cell, an assembly of cells, an assembly of lenses, and an assembly of modules.

The program includes 120 possible module designs representing concentrators of 200 ×, 500 ×, and 1000 ×. These 120 designs are put through 500 trials with SIMRAND. A second program is then used to examine a selected subset of the SIMRAND cases; for example, only 200 × concentrators or only concentrators contained in plastic housings with heat sinks. The input variables include the efficiency of the lenses, the time value of money, and the costs of the substrate, heat sink, packaging, interconnections, optical elements, and antireflective lens coatings. These variables are used to produce 34 distributions, such as the baseline cost of silicon, the advanced cost of silicon, the efficiencies of compression-molded lenses, the efficiencies of injection-molded lenses, the costs of plastic housings, and the costs of aluminum housings.

The documentation contains instructions on how to alter the number of designs, the number of distributions, and the probability of failure and the associated cost of failure for each distribution. The ouput includes the mean and standard deviation for each cost equation, a cumulative histogram for each cost equation, and a histogram of how many trials each module design won.

This program is written in FORTRAN 77 for batch execution and has been implemented on the IBM PC computer series under DOS (2.0 or higher) with a minimum central-memory requirement of 256K of 8-bit bytes. Two double-sided, double-density flexible-disk drives, or one megabyte of hard-disk space is also required. This program was developed in 1986.

This program was written by C. S. Borden and D. L. Schwartz of Caltech, and M. C. Davisson of Apogee Computer Designs, Inc., for **NASA's Jet Propulsion Laboratory** *NPO-17042 /TN*

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Department of Energy

Technology Application

Solar Energy Research Institute

Atmospheric Optical Calibration System Simplifies Spectral Measurements

Background

Outside the earth's atmosphere, the sun provides an essentially constant source of radiant energy. However, a variety of factors (including location, time of day, time of year, haziness, ground reflections, and water vapor) affect the amount and character of solar energy that reaches the earth's surface.

When researchers test photovoltaic (PV) devices under outdoor ambient conditions, they correct their measurements for the differences between the actual radiation falling on the devices and radiation that would fall on the devices under standard conditions. This allows them to correct for variations in atmospheric conditions that affect the sun's spectrum, such as the amount of water vapor and haziness. The sun's spectrum is its power per unit area per unit wavelength. It extends from a lower wavelength of about 0.3 micrometers (in the ultraviolet) to about 4.0 micrometers (in the infrared).

One way to make this correction involves measuring the performance of a "reference" PV device at the same time as the test device, and correcting the performance of the test device to the performance of the "reference" device. But assuming that the test device responds in the same way to the sun's spectrum as the "reference" device leads to errors. Another way is to measure the actual solar spectrum with a spectroradiometer, and correct the performance of the test device for the variation of the actual spectrum from the standard solar spectrum. But spectroradiometers are expensive, difficult to calibrate, and provide data that does not relate directly to device performance.

The AOCS at work. Global horizontal instrumentation on platform (top), beam module on solar tracker (center), and computer at bottom. An additional tracker holds instruments for global tilt/global normal measurements.

Accomplishments

Researchers at the Solar Energy Research Institute have developed an Atmospheric Optical Calibration System (AOCS) that provides a rapid, low-cost way to measure optical properties of the atmosphere. It consists of easy-to-use, readily-available instruments: microprocessors, and a computer model that calculates the ambient solar spectrum. Researchers measure the sun's spectrum with the AOCS at the same time as they measure the PV performance, allowing corrections to be made in real time. If atmospheric and spectral conditions are too far from standard to correct, the system indicates this to the researcher and the PV test may be postponed.

Instrument components in the AOCS measure parameters such as air pressure, direct normal solar irradiance at strategically selected wavelengths, direct normal flux density, and total radiant energy. These parameters go into a computer program that calculates a solar spectrum from 0.3 to 4.0 micrometers. Then this solar spectrum is used to correct the PV device performance to what it would be under standard spectral conditions.

Benefits

The AOCS was designed to benefit researchers in photovoltaics But it is also a valuable tool for any field where knowledge of the spectral properties of solar radiation is important (such as air quality, daylighting, solar thermal) And for an estimated cost of only $5,000 each, this system can provide data from a wide variety of geographic locations

The AOCS direct-beam module consists of four narrow-beam autosunphotometer channels (right) and two broad-beam channels (left) The narrow autosunphotometer channels measure atmospheric aerosol and water vapor, while the broad-beam channels measure total solar irradiance over defined spectral ranges

Additional Information

Publications

Bird, R E., and Riordan, C J "Simple Solar Spectral Model for Direct and Diffuse Irradiance on Horizontal and Tilted Planes at the Earth's Surface for Cloudless Atmospheres" *J of Climate and Appl. Meteorology*, No 1, (Jan 1986), 87-97.

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SERI/SP-260-2734/R-1

Solar Energy Research Institute

Luminance Mapper Model 2

Background

Luminance mappers provide information on lighting conditions in both outdoor and indoor environments. While conventional luminance mappers can determine the quantity and direction of light, they often cannot determine details on its quality. This information would be useful to architects and other professionals in the design of agreeable, energy-efficient lighting systems.

Conventional mapping devices include single-scan detectors and detector arrays. Single-scan detectors require many time-consuming measurements, limiting their usefulness in rapidly changing light conditions. Detector arrays can be extremely expensive since they employ many individually calibrated sensors.

In addition, many conventional mappers are too bulky for fieldwork and too large for use in architectural scale models. These drawbacks limit the range and type of luminance maps available for effective daylighting studies.

A SERI researcher makes indoor luminance readings using the luminance mapper. The viewing assembly and camera are on the tripod, facing upward. A single cart holds the computer and monitors.

Accomplishments

Researchers at the Solar Energy Research Institute (SERI) are pioneering daylighting research with the development of a unique photometric mapping device.

SERI's Luminance Mapper Model 2 (LM2) consists of a viewing assembly, a solid-state video camera, and a computerized workstation. The system is able to scan a full 180° field of view, digitizing and recording an image in about 0.03 seconds. Researchers then can use the recorded luminance data to create contour maps, surface maps, histograms, and data summaries for on-the-spot analysis.

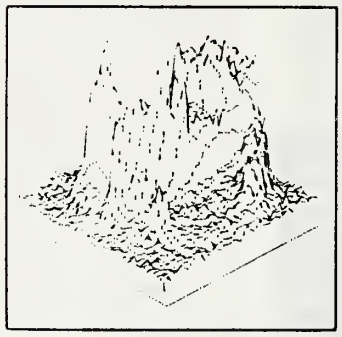
SERI's prototype uses a 10-mm (extreme wide-angle) orthographic lens to first project a primary image onto a ground-glass focusing screen. The primary image is then reduced by a 50-mm transfer lens and filtered so that the system's response to light will be similar to that of the human eye.

The filtered image is picked up by the video camera's solid-state array, a matrix of photosensitive spots precisely located on a substrate material. The array uses a parallel sampling process to transfer the image to a digitizing board within the desktop compu-

ter Digitized data can be transmitted to the video monitor for immediate viewing, or they can be stored on an internal hard disk

Researchers can recall the stored images for immediate manipulation and analysis by using the LM2's AT-class microcomputer System software includes commercially available image-manipulation routines and SERI-developed image-analysis routines With this software and the computer keyboard (or mouse), researchers can determine the luminance of a specific point or area, project isocontours, and create a variety of useful graphics

The LM2 prototype has demonstrated its ability to capture fast, high-resolution luminance flux maps in both interior and exterior environments These maps reflect the quality of light as well as its quantity and distribution SERI researchers now are working under a grant from DOE's Office of Solar Heat Technology to study lighting conditions in building atria.



Overhead brightness map from a light distribution study conducted at the Solarium Building in Englewood, Colo Peaks correspond to bright areas of sky viewed through the glazing Troughs represent the darker sidewalls and shutters

In addition, SERI is seeking the cooperation of lighting instrumentation manufacturers to further LM2 development Planned improvements to the system include calibration of additional lenses to narrow the field of view The LM2 may also be modified to detect color and to measure radiant bands above and below the visible range

Applications

With its compact size and handheld viewing assembly the LM2 has great potential to evaluate light in architectural scale models and to predict interior lighting problems such as glare It may also be used in existing buildings to determine the most efficient use of light.

Outdoors, the LM2 may be used to study the impact of cloud cover on daylighting research and to compile images for sky modeling studies Researchers can use these data as part of an international effort to measure and model the daylighting resource

Benefits

The LM2 can mathematically process a recorded image to provide information on light quality, quantity, and direction. It therefore has the potential to expand the range and type of luminance maps available to daylighting researchers In addition, the LM2's imaging capability permits immediate visual and quantitative daylighting research

Additional Information

Publications

Balcomb, J.D., and Weaver, N. (1987) "Photometric Measurements in Atria Using the Luminance Mapper." *Solar '87*, American Solar Energy Society Conference, Portland, OR. Held in July 1987

Cannon, T.W., and Dwyer, L.D. (1981) *An All-Sky, Video-Based Luminance Mapper for Daylighting Research*. SERI/TP-643-1324 Golden, CO: The Solar Research Institute.

Weaver, N.L.; Robbins, C.L.; Hunter, K.C.; and Cannon, T.W (1986). "Development of a Second-Generation, Video-Based Luminance Mapper for Daylighting Research." *Proceedings of the Second ASHRAE International Daylighting Conference*, Long Beach, CA.

Contacts

Business Information: SERI Industry Affairs, (303) 231-7115
Technical Information: SERI Technical Inquiry Service, (303) 231-7303

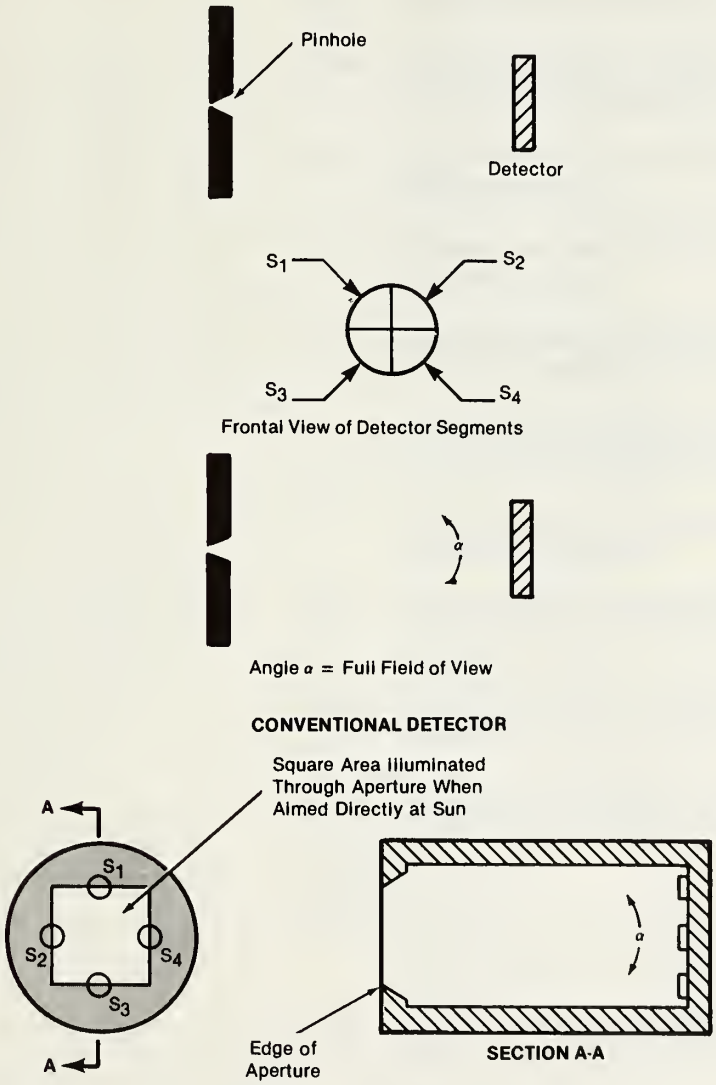
SERI/SP-260-2734/R-3

NASA Tech Brief
National Aeronautics and Space Administration
Ames Research Center, Moffett Field, California

Licensing Opportunity

Compact Sun-Position Sensor

A single device finds and tracks the Sun.



The **Conventional Sensor** (above) can have a wide field of view or high angular resolution but not both. The new sensor (below) has both a wide field of view and high angular resolution when its axis is within a few degrees of the line to the Sun.

A light sensor combines a wide field of view with high resolution so that it can be used for both finding and tracking a moving light source like the Sun. The sensor was developed as a smaller, lighter, and simpler replacement for an instrument that employed two sensors — one with coarse resolution and a wide field for finding the Sun and one with fine resolution and a narrow field for following the moving Sun after it has been found. Previously, the integration of the two types of sensors introduced mechanical and electronic complexity.

A conventional Sun-position sensor (see top of figure) includes a single photodetector divided into four quadrants, on which a spot of light is projected from a pinhole aperture. To increase the field of view, the diameter of the detector can be increased, or the distance between the aperture and detector can be decreased. However, the diameter should be small to keep noise and response time short. Moreover, decreasing the aperture distance makes the detector less sensitive to changes in spot position. Thus, a wide field of view is incompatible with high resolution.

The new sensor contains four photodetectors spaced 90° apart on a circle opposite the square aperture of a small cylindrical chamber (see bottom of figure). The aperture casts equal shade on the detectors when the cylinder axis points directly at the center of the Sun. Upward or downward movement of the Sun places one of the vertical-motion detectors in more shade and the other in less shade. The difference in the outputs of the two vertical-motion detectors S_1 and S_3 is therefore an elevation-error signal. Similarly, sideways motion of the Sun changes the shade on each of the horizontal detectors relative to the other so that S_2 and S_4 generate an azimuth-error signal. The detectors can be photovoltaic cells or photoresistors.

This work was done by Yutaka Matsumoto and Cesar Mina of **Ames Research Center**. *No further documentation is available.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Ames Research Center
Refer to ARC-11696, TN

Ames Research Ctr.
Moffett Field, CA 94035
Technology Utilization Officer Laurance Milov
Mail Code 223-3
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Mail Code 200-11
(415) 694-5104

FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD 21240; (301) 621-0100 Ext. 241*
REFER TO THE NUMBER LISTED AT THE END OF THIS ARTICLE

Engineering

371 Modified Trawling Efficiency Device

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377 Collector/Compactor for Waste or Debris — A stretchable net gathers loose material and compresses it.

378 Control and Simulation of Space-Station Vibrations — An adaptive control system can reduce the effects of model uncertainties.

379 Designing a Transonic Nozzle for Efficient Cooling — Throat curvatures are adjusted to match maximum heat flux with maximum heat removal.

380 Effects of Structural Errors on Parameter Estimates — The information content of a measurement is defined.

381 Repairing Holes in Pressure Walls — Patches and easy-to-use tools yield a pressure-tight seal. (Licensing Opportunity)

382 Steam Reformer with Fibrous Catalytic Combustor — Heat transfer would be more controllable. (Licensing Opportunity)

383 Truss-Core Corrugation — The strength-to-weight ratio exceeds that of the beaded-web design by 60 percent. (Licensing Opportunity)

Software

384 Calculating Transport of Moisture Through Honeycomb Panels — Diffusion equations are solved for steady-state and transient conditions.

385 Steady-State Thermal-Analysis Program for Microcomputers — A nodal-network model of heat flow is implemented by a computer program.

Testing & Instrumentation

386 Portable Test and Monitoring System for Wind-Tunnel Models — Model instrumentation can be tested in or out of the wind tunnel. (Licensing Opportunity)

387 Water-Tunnel Flow Visualization with a Laser — Experimental conditions for effective visualization are determined. (Licensing Opportunity)

Other Items of Interest

343 Position and Force Control for Multiple-Arm Robots — The number of arms can be increased without introducing undue complexity.

429 Swivel Joint for Liquid Nitrogen — The joint is compatible with hard foam insulation.

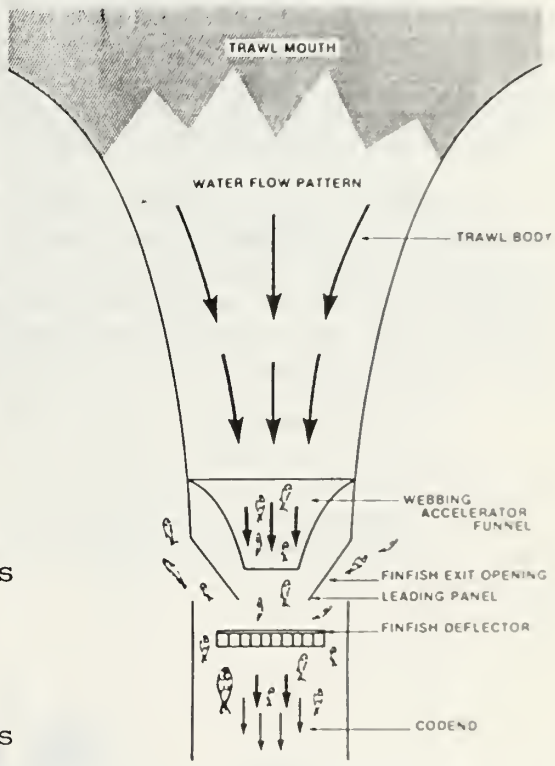
NOAA Technology Brief

National Oceanic and Atmospheric Administration

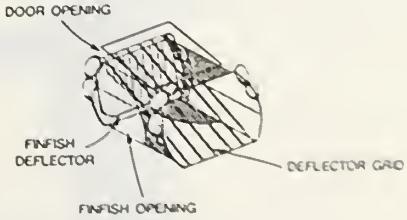
National Marine Fisheries Service
Southeast Fisheries Center, Mississippi Laboratories

Modified Trawling Efficiency Device

The trawling efficiency device (TED), which evolved from the turtle excluder device, utilizes differences in the behavioral reaction of finfish and shrimp and the better swimming ability of the fish to separate and exclude fish from a catch. The TED is located before the cod end of the trawl. A funnel of webbing in the TED accelerates water flow, carrying the weak swimming shrimp into the cod end. Finfish actively swimming in the trawl also pass through the funnel in the accelerated water flow, but are stimulated by the closeness of the webbing to escape the trawl.



As the fish pass through the funnel, they either strike the finfish deflector, a recent modification, or enter an area of less water flow to the side of the main flow. There, fish are guided by webbing panels and can leave the trawl through side exits. Shrimp have neither the swimming ability nor behavior necessary to reach the exit openings and are carried on into the cod end. Larger objects or organisms that cannot pass through the 3- to 6-inch openings of the main deflector grid are ejected through a hinged door at the top of the TED.



In earlier designs, finfish separation rates up to 53 percent were achieved during the day compared with standard trawling gear, but only 10 percent separation was achieved during nighttime trawling. One new modification is a small deflector frame, called the

finfish deflector grid. It is located at the rear of the TED and results in improved finfish separation rates averaging 78 percent during the day and 48 percent at night. The finfish deflector grid acts as a mechanical stimulus and generates sound vibrations.

The original rigid-frame TED weighed 97 pounds and required considerable deck space for storage. To help the shrimp fishermen solve the handling and storage problems connected with this gear, a collapsible frame was developed.

The collapsible TED is constructed from 3/8-inch steel pipe. It is hinged between front and rear frames and the main deflector grid, enabling the device to fold to a flat position when not in use. When fishing, tension in the trawl opens the TED to its working configuration. The design is equipped with a finfish deflector grid that is constructed of 5/8-inch fiberglass tubing and 1/16-inch stainless steel strand cable.

More details on these modifications and information on field testing of the different TEDs can be found in a report by John W. Watson and John F. Mitchell of the Mississippi Laboratories and Arvind K. Shah of the University of South Alabama. A copy of the paper or additional information can be obtained by writing NOAA ORTA, Suitland Professional Center (SPC), Room 307, Suitland, Maryland 20233; or by phoning (301) 763-4240.

Anchor Developed to Meet High-Capacity Fleet Moorings

A new high-capacity drag embedment anchor called NAVMOOR has been developed at the Naval Civil Engineering Laboratory.

The NAVMOOR anchor was originally developed for the Naval Facilities Engineering Command to meet the anchoring needs of new high-capacity Fleet moorings. However, this new anchor is also suited to many other anchoring applications. Current anchor sizes range from 100 to 15,000 pounds.

The NAVMOOR anchor flukes are streamlined, hollow shells that enable good penetration in hard soils and provide the excellent resistance to bending that is needed for hard soil and coral applications. Large mud palms are permanently affixed to the anchor to ensure reliable fluke tripping (opening) in soft soils.

For tandem anchor (also called piggyback anchor) hookup, the anchor shank extends through the anchor crown and connects to the pinned tandem link. The through-crown hookup method eliminates the possibility of the primary anchor flukes' closing during tandem anchor loading. The anchor shank and fittings were designed to hold 2-1/2 times the capacity of a single anchor to allow full development of tandem anchor system capacity. Anchor assembly or disassembly can be accomplished in minutes to simplify shipping and storage. The stabilizers on standard

NAVMOOR Anchor

Anchor fluke angles can be adjusted from the soft soil setting of 50 degrees to the sand/hard soil setting of 32 degrees by tack-welding sand wedges to the fixed stopper assembly.

The anchors can be fabricated from wrought steel, forgings, and castings. The most economical and effective fabrication means employs a combination of casting and welded construction. Most of the components except the anchor flukes are cast. The flukes are fabricated from wrought steel and then welded to the cast anchor palm.

For Additional Information:

Backup material on this effort is available from:

Navy Domestic Technology Fact Sheet
Reader Reply Service,
Code E211,
Naval Surface Weapons Center,
Dahlgren, VA 22448-5000
(703) 663-8921

Refer to 120801/TN

NBS technology update

National Bureau of Standards
U.S. Department of Commerce
Gaithersburg, MD 20899

Federal Technology Resource

Bulletin Board Started on Fire Research Programs

Many of the computer programs developed by the NBS Center for Fire Research (CFR) now can be obtained 24 hours a day, 7 days a week through a computerized bulletin board called CFRBBS. Included are computer programs which simulate the movement of smoke and toxic gases and the decisions and actions of occupants during a fire as well as a program which can help analyze smoke control systems. Information on upcoming CFR activities, such as conferences; a list of recent CFR reports; and information on accessing FIREDOC (a computerized fire research database) also is available on the bulletin board. It is designed to operate with IBM personal computers or compatible computers. The modem telephone number is 301/921-6302. The bulletin board operates at 300, 1200, or 2400 BAUD with most PC communications packages. The package should be set for 8 data bits, 1 stop bit, and no parity. Xmodem, Ymodem, Crxmodem, or Kermit protocol is required to download most of the files. No password is needed and there is no fee other than telephone costs paid by the user.

FOR ADDITIONAL INFORMATION: Contact system operator Doug Walton, National Bureau of Standards, Germantown, MD 20899; (301) 975-6872

Measurement and Testing

03-01-0188

Acoustic Solid/Gas Flowmeter

Direct monitoring in solids transport lines

One of the greatest problems in pneumatic transport of solids has been feedrate measurement, which is needed for material control. At present, the only way to measure solids feedrate is to monitor the solid weight in hoppers. Direct monitoring in transport lines is unavailable. Conventional methods such as venturi and pitot tube devices cannot be used because of the abrasive and erosive nature of a solid/gas flow. Such devices often experience plugging or erosive damage, and require extensive repair and calibration.

Argonne National Laboratory has developed an acoustic solid/gas flowmeter that is nonintrusive, and requires no calibration because it measures the transit time of solid particles. The instrument is portable and can be applied to high-temperature high-pressure environments. The flowmeter is unique and offers the solution to a problem common to many industries.

In solid/gas flow within a pipe, particles striking the pipe produce an acoustic noise signal whose magnitude and frequency are related to particle momentum and number of impinging particles, respectively. Thus, the noise signal characteristic is pertinent to the particle flow in the pipe. Measurement of such a noise signal at two locations along the pipe will then derive the particle velocity. The acoustic flowmeter uses two sets of transducers, isolated acoustically to avoid any signal cross-talk. Of each set, one transducer is used to produce an acoustic field in the pipe. When particles impinge on the pipe, the acoustic field will be modulated by the impingement noise. The flow-related noise signals at the two sensing regions can then be extracted by a demodulations scheme and cross-correlated to give the transit time measurement, from which particle velocity can be derived.

Additional Information

Key Words: pneumatic transport, solids, feedrate, solid/gas, flowmeter

Patent Status: U.S. Patent No. 4,598,593.

Potential Applications: Direct monitoring in solids transport lines.

Spinoffs: None.

Literature: Development of Acoustic Flow Instruments for Solid-Gas Pipe Flows. S. H. Sheen and A.C. Raptis. ANL Report ANL/FE-85-07, Argonne National Laboratory, Argonne, IL (May 1986).

For More Information: Contact the Technology Transfer Center, 9700 S. Cass Ave., Argonne, IL (312/972-7694).

NBS technology update

National Bureau of Standards
U.S. Department of Commerce
Gaithersburg, MD 20899

The Characterization of Microenvironments and the Degradation of Archival Records: A Research Program

Librarians and archivists concerned with the degradation of paper materials stored in containers will be interested in The Characterization of Microenvironments and the Degradation of Archival Records: A Research Program (NBSIR 87-3635). The report was prepared by NBS for the National Archives and Records Administration 9NARA) at the suggestion of a National Academy of Sciences (NAS) committee convened to study the preservation of historical records. NAS recommended that NARA conduct a study of archival containers and microenvironments, including boxes, folders, and polyester encapsulation to understand the maximum benefits from particular materials and designs. The NBS report describes the issues involved in assessing the effect of the microenvironment on the degradation of materials. Some examples are given to illustrate how air pollutants can be exchanged between the inside and outside of containers by diffusion through container walls or through gaps and openings, and by the effects of pressure and temperature changes. The problems of complete sealing or encapsulations of documents are discussed because of the possibility of autocatalytic degradation.

FOR ADDITIONAL INFORMATION:

A full description of this activity is contained in a backup report which may be purchased from NTIS, Springfield, VA 22161; (703) 487-4650.

NTIS order number: PB88-128996/NAC
Price code: A07

NASA Tech Brief
National Aeronautics and
Space Administration

Coal-Fired Rocket Engine

A proposed hybrid engine would combine solid fuel with liquid oxidizer.

A brief report describes a concept for a coal-burning hybrid rocket engine. The proposed engine would carry a larger payload, burn more cleanly, and be safer to manufacture and handle than are conventional solid-propellant rockets. Its thrust would be changeable in flight, and it could be stopped and started on demand.

The coal-burning rocket engine could be used in boosters, upper stages, and intermittent thrusters (for station-keeping and course correction, for example). It could also be used as a gas generator or electrical-power generator. It could supply energy for high-intensity lasers on spacecraft, for instance.

Unlike ordinary solid-propellant engines, the coal-burning engine would not release large amounts of hydrogen chloride into the atmosphere during a launch. At the same time, it would offer higher performance at lower cost.

The fuel would consist of powdered coal and aluminum powder in a high-molecular-weight, rubbery polymer matrix. This solid fuel would be burned with liquid oxygen in the rocket motor. The solid fuel would be processed as a case-bonded unit. In the processing, shipping, and assembly stages, the fuel units could be handled as inert units from a safety standpoint.

This work was done by Floyd A. Anderson of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "High Performance, Clean Burning Propulsion System," NPO-16902 /TN*

FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD. 21240; (301) 621-0100 Ext. 241*

REFER TO THE NUMBER LISTED AT THE END OF THE ARTICLE

NASA Tech Brief
National Aeronautics and Space Administration

Collector/Compactor for Waste or Debris

A stretchable net gathers loose material and compresses it.

Lyndon B. Johnson Space Center, Houston, Texas

A device collects and compacts debris by sweeping through a volume with a net. The device, developed for compacting human waste in 2.7-ft^3 (0.076-m^3) storage containers in the microgravity of space vehicles, can have such terrestrial applications as cleaning swimming pools and tanks.

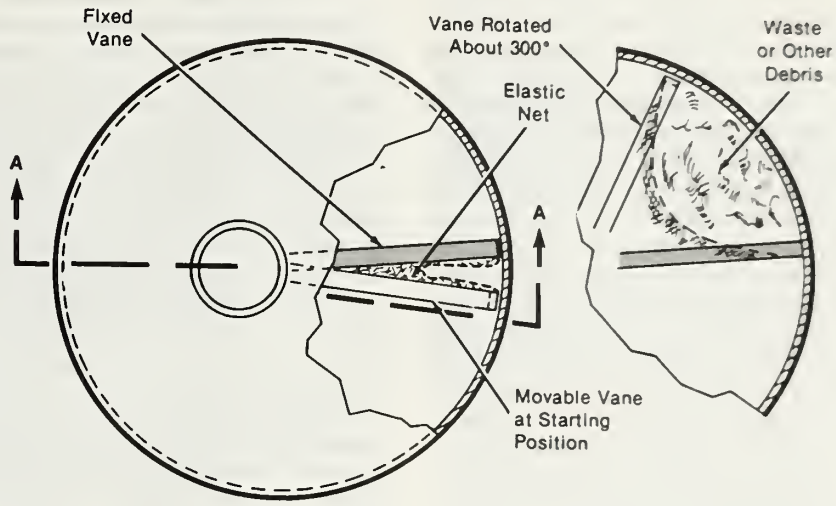
In the space application, a flow of air carries debris into the containers. Without the new device, debris accumulates at the container inlets as the containers become full and the airflow loses effectiveness. By collecting and compacting the debris, the device enables the use of the full volume of the container.

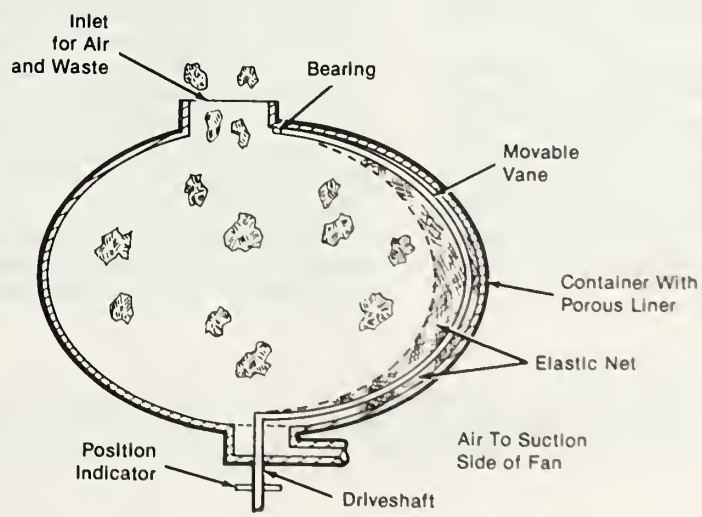
The device consists of a movable vane, a fixed vane, and an elastic net connected to both vanes (see figure). The movable vane is a metal strip curved to follow the general contour of the container but with enough clearance to prevent interference with other parts on the inside wall of the container. One end of the movable vane is mounted in a bearing and the other end is connected to a driveshaft equipped with a handle. When the user rotates the movable vane, the net is stretched and swept through the container. The net captures most of the debris coarser than its mesh as it moves, compressing the debris as it arrives at the fixed vane.

The elasticity of the net accommodates its varying length, which grows as the movable vane rotates to 180° from the fixed vane, then shrinks as it rotates from 180° toward 360°. An external dial on the driveshaft indicates the position of the movable vane.

The elastic net can be made of a stretchable polymer like Spandex (or equivalent) polyurethane, of a combination of extension springs and netting, or of springs alone. The greater the elastic tension, the better will be the retention and compression of waste against the container wall.

The motion of the vane can be reversed after use to collect and compress material in the opposite direction. The device can be used many times.





SECTION A-A

Sweeping Through the Container Volume, an elastic net gathers and compresses debris. The container is thus cleared of most loose material, and its useful capacity is increased.

This work was done by John K. Mangialiardi of General Electric Co. for **Johnson Space Center**. *No further documentation is available.*
MSC-21196/TN

FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD. 21240; (301) 621-0100 Ext. 241*
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NASA Tech Brief
National Aeronautics and
Space Administration

Control and Simulation of Space-Station Vibrations

An adaptive control system can reduce the effects of model uncertainties.

A report outlines a method for the finite-element dynamic analysis of a space station. The purposes are to determine the periods and modes of oscillation of the structure and to analyze the effect of a proposed adaptive control system to damp out unwanted vibrations. With the simplifications proposed by the authors, the finite-element simulations could be performed during a dynamic event, like docking of the Space Shuttle, and used to control the vibration-damping actuators. The general technique, known as direct model reference adaptive control, is used to make the output of an unknown or poorly known system asymptotically track that of a reference model that specifies the desired performance of the system. The technique is also applicable to robotics, seismic control of large buildings, electromechanical systems, metallurgical processes, and large oil tankers.

Two basic space-station configurations were considered. One has two large solar panels at one end of the inhabited module and is asymmetric. The second has four solar panels, two at each end of the inhabited module, and is symmetric. The authors provide a detailed development of the stiffness matrices for these two structures.

With the finite-element technique, the authors perform analyses to determine the natural frequencies and the vibraton modes of the structures. Based on these results, they propose several adaptive control systems to aid in removing the unwanted oscillations. The vibrations would be sensed by accelerometers. The proposed control mechanisms include thrusters, active hinges, control-moment gyroscopes, and reaction wheels at critical points in the structures. Analyses of the behaviors of the structures with the adaptive controls showed that the controls can minimize the motions.

The adaptive control system is augmented by an inner control loop that eliminates the instabilities caused by zero-frequency rigid-body modes. An inner-loop control-gain matrix can be chosen to give the rigid-body modes non-zero frequencies, thereby making it possible to implement a stable, adaptive control system. The inner-loop controller can be made robust — that is, relatively insensitive to dynamic-model errors — by placing the loop only at the location where the rigid-body modes are most controllable.

The system as a whole is robust in the presence of unmodeled dynamics caused by truncation of the mathematical model, poor knowledge of the dynamics of the structure, and instantaneous changes of system mass and mass distribution by more than 100 percent (as in docking of the Space Shuttle). The system has good convergence even under such severe dynamic conditions as high initial elastic deformations and attitude errors, and sudden impact of docking or pushoff.

The high gain required by an ideal adaptive controller will far exceed practical equipment limitations. Gain limitation can be applied to set a practical limit on the control effort and to maintain stability of the system, entailing the penalties of slightly higher transient vibrations and longer settling time. Model switching and disturbance modeling provide means for the reduction of output errors and, therefore, to reduce control demand. To compensate for incomplete knowledge of the structure, some simulation would have to be done for fine tuning.

This work was done by Che-Hang Charles Ih, Shyh Jong Wang, and Yu-Hwan Lin of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report "Space Station Dynamic Modeling, Control and Simulation," NPO-16852/TN*

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NASA Tech Brief
National Aeronautics and
Space Administration
Marshall Space Flight Center, Alabama

Designing a Transonic Nozzle for Efficient Cooling

Throat curvatures are adjusted to match maximum heat flux with maximum heat removal.

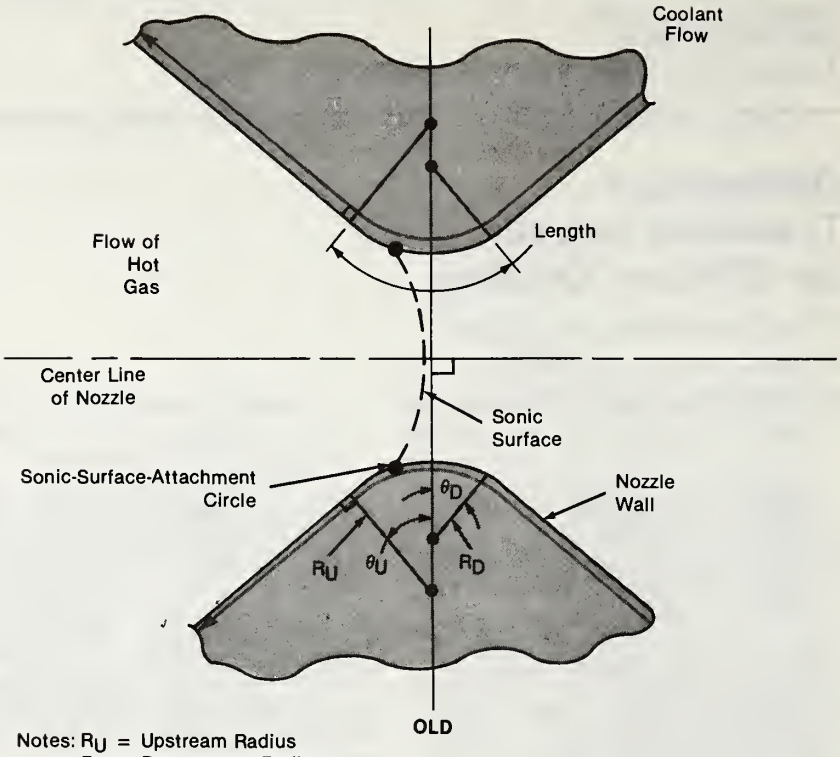
A design for a high-pressure transonic-flow nozzle increases the effectiveness of the coolant flowing in passages in the wall of the nozzle. The revised curvatures of the nozzle wall provide a shortened transonic region and enable the selection of the approach- and discharge-wall angles for maximum cooling. As a result, the new nozzle design enables the wall to operate at a lower temperature, reducing thermal fatigue and increasing the life expectancy of the wall. It also enables the coolant to flow through the wall channels with lower pressure drop and, therefore, lower pumping pressure.

In previous designs, the upstream and downstream radii of the nozzle throat and the two tangency-point angles (see figure) were specified without regard to the position of the sonic point relative to the coolant-channel curvature. In the new design, the radii and the tangency-point angles are selected to give a shorter path for the high-velocity coolant through the channels.

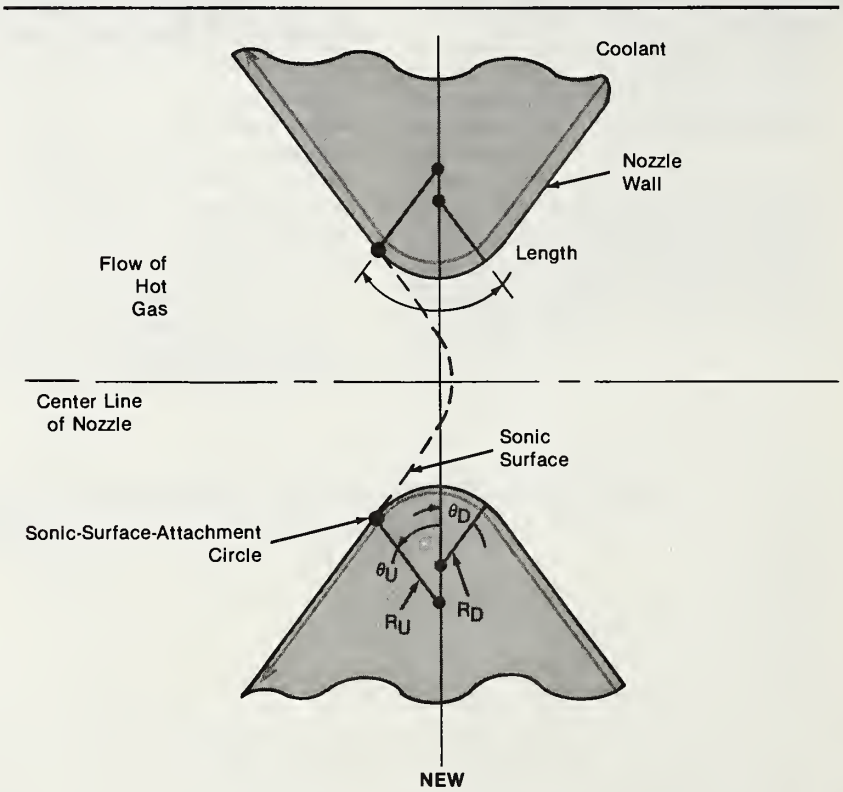
Moreover, the sum of the angles is selected so that the coolant flow acquires a centrifugal-force component that is greatest in the vicinity of the sonic-surface-attachment circle. This means that the area of greatest heat flux from the gas flowing through the nozzle is also the area where the coolant can carry the heat away most effectively; the rate of heat transfer can be increased by as much as 50 percent.

This work was done by William R. Wagner of Rockwell International Corp. for **Marshall Space Flight Center**. *No further documentation is available.*
MFS-29224 /TN

The **New Nozzle Design** reduces the length of the coolant channels in the nozzle wall. At the same time, the greater curvature of the nozzle throat increases the centrifugal effect, and consequently the cooling capacity, without increasing the required pumping power.



Notes: R_U = Upstream Radius
R_D = Downstream Radius
θ_U = Upstream Tangency Angle
θ_D = Downstream Tangency Angle



FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD. 21240; (301) 621-0100 Ext. 241*

REFER TO THE NUMBER LISTED AT THE END OF THE ARTICLE

NASA Tech Brief
National Aeronautics and Space Administration

Effects of Structural Errors on Parameter Estimates

The information content of a measurement is defined.

A paper introduces the concept of the near equivalence in probability between different parameters or mathematical models of a physical system. It is one in a series of papers, each of which establishes a different part of a rigorous theory of mathematical modeling based on concepts of structural error, identifiability, and equivalence. In this installment, the focus is upon the effects of additive structural errors on the degree of bias in estimates of parameters.

A mathematical model is fitted to a system by adjusting the values of parameters in the model. These values are estimated by fitting solutions computed using the model to the physical system. Thus, a quantitative representation of the information content of a measurement expresses the degree to which the measurement enables one to distinguish between different models or sets of parameter values. For real measurements that are subject to error, the information content of a measurement is related to the degree to which the measurement enables one to narrow the probability distribution of the parameter values.

The information content can be expressed in a matrix form reported by prior authors. The present authors show that the nonsingularity of the information matrix is a necessary and sufficient condition for the near equivalence in probability between a model and a system in the presence of several error sources. The resulting formulation makes it possible to evaluate the effects of modeling errors by comparing the output probability densities of the model and the system. This technique is applicable to both deterministic and stochastic errors.

The problem of identifiability of a model is then approached through the evaluation of the information matrix for nearly equivalent models. For a deterministic modeling error, the covariance of the error of the parameter estimates turns out to be independent of the structural-error term. However, a random modeling error can increase the variance of errors and contribute to considerable bias in the parameter estimates.

In this study, the unknown parameters were assumed to be deterministic constants. In principle, appropriate modifications of the definitions of near equivalence could enable the extension of the theory to models with random parameters. The effects of random parameters and multiplicative modeling errors on the near-equivalence and the parameter-identifiability problems also remain to be investigated.

This work was done by F. Y. Hadaegh and G. A. Bekey of the University of Southern California for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "Effects of Structural Error on the Estimates of Parameters of Dynamical Systems,"*
NPO-16816/TN

FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD. 21240; (301) 621-0100 Ext. 241*
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NASA Tech Brief
National Aeronautics and Space Administration

Licensing Opportunity

Repairing Holes in Pressure Walls

Patches and easy-to-use tools yield a pressure-tight seal.

Marshall Space Flight Center, Alabama

A method of repairing punctures in pressure walls is straightforward, neat, and fast. Developed for closing holes caused by the impact of orbiting debris or micrometeoroids on spacecraft, the method employs a patch precoated with adhesive.

The patch (see figure) includes a disk of soft aluminum about 8 mils (0.2 mm) thick. A backing sheet on the cushion covers the adhesive until the patch is used. A Kevlar® aramid cushion in the central portion of the patch protects the aluminum from the sharp, ragged edges of the puncture. The patch is thin enough to conform to surface irregularities. Nevertheless, it can be handled — and the cover on the adhesive can be removed — by an operator wearing heavy gloves.

The repairer first uses a tool with an abrasive pad to smooth the sharp edges of the hole and to remove paint and loose material. With a cleaning pad on the same tool, the repairer collects dust and chips on the surface (the cleaning pad is layered so that the user can discard a dirty layer and expose a fresh one as necessary).

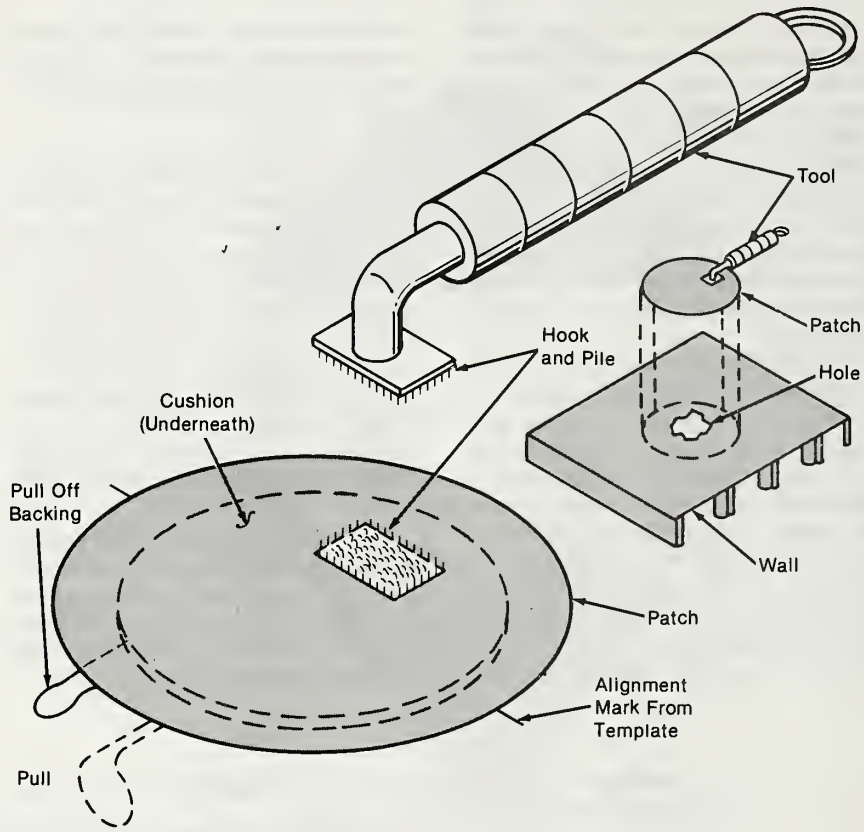
The repairer places an alignment template over the puncture, positioning the template crosshairs over the center of the hole. With a marker, the repairer draws locator lines at three or more places on the wall at the periphery of the template, then removes the template.

The repairer picks up the patch with a hook-and-pile tool and tears off the backing. With the adhesive side of the patch toward the wall, the repairer aligns the patch with the locator lines. The repairer presses the patch edge firmly against the wall and then uses a tool to burnish bubbles, folds, and creased edges on the patch.

This work was done by Paul Bruce Y. Mori, Laurie J. Capriloa, Alexander R. Corocado, Martin N. Gibbins, and Robert B. Horne of the Boeing Co. for **Marshall Space Flight Center**. *For further information contact the Patent Counsel, Marshall Space Flight Center.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center.

Refer to MFS-28179/TN



A **Repairer Lifts a Patch** from a repair kit with a hook-and-pile-tipped tool and positions it over a puncture hole. With the tool, even a gloved repairer can easily manipulate the patch without damaging it.

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NASA Tech Brief
National Aeronautics and Space Administration

Licensing Opportunity

Steam Reformer With Fibrous Catalytic Combustor

Heat transfer would be more controllable.

NASA's Jet Propulsion Laboratory, Pasadena, California

A proposed steam-reforming reactor would derive its heat from internal combustion on a fibrous catalyst. The supplies of fuel and air to the combustor could be controlled to meet the demand for heat for the steam-reforming reaction. Such control could also enable the use of less expensive reactor-tube material by limiting the temperature to a value that is safe for the material yet not so low as to reduce the reactor efficiency.

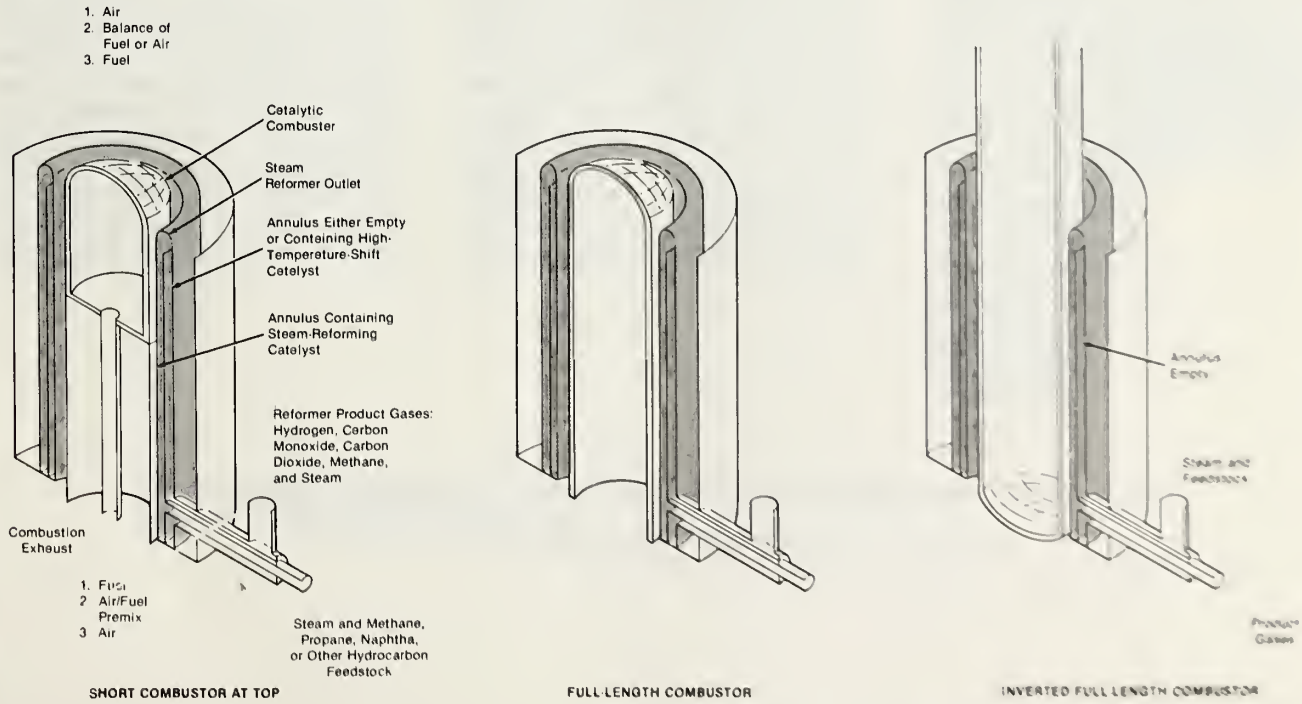
The new reactor concept combines the catalytic combustor with an annular steam reformer (see figure) to enhance the transfer of heat into the steam-reforming catalyst and thereby raise the efficiency. The combustor catalyst is applied to the outer portion of a shell of fibrous alumina, silica, or other suitable oxide material.

A gaseous fuel, fuel/air premix, or air is fed to the hollow inside of the combustor and diffuses out through the fibrous material. To maintain the fuel/air ratio necessary for combustion and to meet the heat-flow requirement, a flow of air, air/fuel premix, or fuel, respectively, is directed over the outer surface of the combustor. The inside and outside gas flows meet and react on the combustor wall, and the resulting heat is radiated onto the inside wall of the steam reformer.

The hot combustion exhaust gas flows through the space between the combustor and the reformer, convectively transferring additional heat to the reformer. The space between the combustor and the reformer can be filled with fins or with porous or fibrous metal or ceramic to enhance the heat transfer. The size of this space and the precise nature of the packing can be chosen to meet the heat-transfer and pressure-drop requirements.

The relative sizes of the combustor and reformer are also chosen according to the heat-transfer requirement. Typically, the outlet end of the steam-reformer catalyst bed requires less heat per unit area than does the inlet end, but the temperature of the steam-reforming product gases must be raised into the range of 1,500 to 1,700 °F (800 to 900 °C) to increase the degree of conversion in the reactor. The combustor design is compatible with the gas flows at the exit end of the steam reformer to provide the necessary temperature rise without overheating the reformer tube or any of the surrounding materials.

Refinements of the design could distribute the heat flux in a manner that increases the degree of conversion and the efficiency in the particular system in which the reformer is incorporated. For example, the combustor could be segmented for different air/fuel flows to its upper and lower ends. This would make it possible to concentrate the heat flux at the lower end of



The **Steam-Reforming Reactor** is made of concentric tubes, with the steam-reforming catalyst in the innermost annular segment. Heated by the catalytic combustor, the reactor converts steam and a feedstock gas into a product-gas mixture. Such a reactor could be used to produce hydrogen or synthesis-gas mixtures.

the combustor, where the steam-reforming reactor requires the most heat. For another example, the air could be added at the top at more than the stoichiometric ratio, so that not all of the oxygen would be consumed at the top. A secondary flow of fuel through the lower part of the fiber catalytic combustor would provide the additional heat needed below by the steam reformer.

In another version, the combustor would occupy the entire length of the reactor, and the flows of fuel and air would be distributed along the length in a pattern designed to give the required temperature and heat-flow distributions. In yet another version, the combustor would be turned upside down and the direction of flow in the inner reformer annulus would be reversed.

This work was done by Gerald E. Voecks of Caltech for **NASA's Jet Propulsion Laboratory**.

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, NASA Resident Office-JPL.

Refer to NPO-16971/TN

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NASA Tech Brief
National Aeronautics and Space Administration
Langley Research Center, Hampton, Virginia

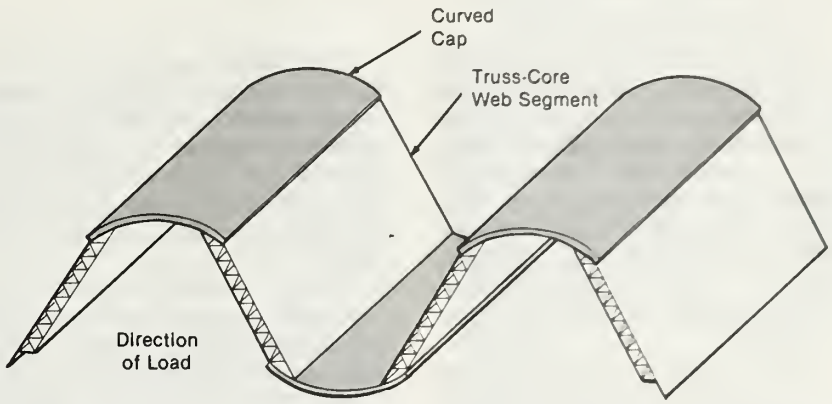
Licensing Opportunity

Truss-Core Corrugation

The strength-to-weight ratio exceeds that of the beaded-web design by 60 percent.

The need for lighter and stronger primary structures for high-altitude, high-speed aircraft and for spacecraft motivates the search for minimum-mass fuselage and fuel-tank structures. Such craft normally require external protection systems; therefore, the underlying primary fuselage or tank structures need not be aerodynamically smooth. The limiting loads in such structures are primarily those that cause compression buckling of the wall sections. In this respect, corrugated structures offer the most attractive strength-to-weight efficiencies. A new corrugation design offers a significant weight saving over previous concepts for a wide range of loading. In this design, the beaded web of prior concepts is replaced by a truss-core web, improving the strength-to-weight ratio over that of existing structures by as much as 60 percent.

The low-mass-fraction truss-core web design is shown in the figure. The truss-core web-to-cap joint provides rotational restraint for the cap, enabling the cap to carry its portion of the design load without edge rotation or premature local buckling. In the beaded-web corrugation, as much as 60% of the panel mass does not carry a load. The truss-core web is fully load carrying as are the caps, enabling the structure to support a much higher load at the same weight as that of the beaded-web, curved-cap corrugation.



The **Truss-Core Web** replaces the beaded web of previous corrugation designs.

Within the truss-core web, the cross-sectional properties are optimized to provide the web of lightest weight for the load to be carried. The truss-core corrugation and cap can be made of metallic or nonmetallic materials or appropriate combinations thereof. Structures of any width can be made by repeating any number of corrugation segments. Further, these sections can be repeated on curves to form the walls of such shell structures as cylindrical shells for fuselages and fuel tanks. Also, the cap strips can be extended and crimped over the truss-core webs, improving the damage resistances of the caps and further stabilizing the cap edges against rotation.

This work was done by Randall C. Davis and L. R. Jackson of **Langley Research Center**.

This invention is owned by NASA, and a patent application has been filled. Inquiries concerning nonexclusive or exlusive license for its commercial development should be addressed to the Patent Counsel, Langley Research Center
Refer to LAR-13438./TN

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Calculating Transport of Moisture Through Honeycomb Panels

Diffusion equations are solved for steady-state and transient conditions.

HUMID is a computer program for predicting the moisture gradients and internal bursting pressure in composite honeycomb-sandwich panels. Advanced multilayer composite structures are usually degraded by absorbed moisture when subjected to high temperatures. HUMID was designed to monitor the ebb and flow of moisture in the Space Shuttle Orbiter payload bay doors, but is applicable for general use.

A sandwich panel consists of many layers of different materials with adhesives and facesheets surrounding a ribbon of honeycomb core. Absorbed moisture causes swelling and may alter the mechanical properties of a material. Moisture is transported to the core from the surface skin via rapid diffusion through trapped air. This phenomenon can be satisfactorily modeled by Fick's diffusion laws for both steady-state and transient conditions.

The diffusion response of each layer of different material to boundary humidities is represented in HUMID by a linear partial differential equation. The equations of all the layers are solved simultaneously with the ideal-gas law to yield structural moisture levels as a function of the environment.

The input to HUMID consists of such sandwich-layer parameters as thicknesses, densities, permeabilities, break temperatures, water solubilities, etc., and such environmental factors as the initial humidity of the layers; the duration of the flight; and the temperatures of the core and outer skin during ascent, re-entry, and cool-down. Typical HUMID results include the average moisture content of each layer of material. The contribution of water-vapor pressure to the honeycomb-sandwich internal pressure as a consequence of heating is also calculated. The internal bursting pressure and structural margins of safety can also be determined. HUMID produces plots of the moisture content against time, the temperature against time, and the margin of safety against time.

HUMID is written in FORTRAN for batch execution and has been implemented on an IBM 360-series computer operating under OS with a central-memory requirement of approximately 501K of 8-bit bytes. This program was developed in 1985.

This program was written by R. T. Martin and D. J. Zigrang of Rockwell International Corp. for **Johnson Space Center**.
MSC-21144 /TN

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NASA Tech Brief
National Aeronautics and Space Administration

Steady-State Thermal-Analysis Program for Microcomputers

A nodal-network model of heat flow is implemented by a computer program.

The Steady State Thermal Analysis Program (STEADY) provides the thermal designer with a quick and convenient method for the calculation of heat loads and temperatures. STEADY can be used on small nodal networks for conceptual or preliminary thermal design and analysis. STEADY will accept up to 20 nodes of fixed or variable temperatures, with constant or temperature-dependent thermal conductivities, and any set of consistent units.

In a steady-state thermal network, the heat balance on each variable-temperature node must sum to zero. The general heat-transfer equations are solved with a Newton-Raphson technique and refined by a fourth-order quartic solution. The input data include the number of nodes, the number of boundary nodes, the fixed temperatures at all boundary nodes, the initial guesses of the temperatures at the variable-temperature nodes, impressed heat loads, conduction and radiation coefficients, and such control parameters as convergence criteria, the maximum number of iterations, and damping factors. The output is stored in a print file, which tabulates final temperatures and heat flows for all nodes. STEADY is menu-driven and allows the user to save files for future modification.

STEADY is written in FORTRAN 77 (Ryan McFarland's RMFORTRAN) for interactive execution and has been implemented on the IBM PC computer series under DOS with a central-memory requirement of approximately 92K of 8-bit bytes with a math coprocessor, and 103K bytes without the coprocessor. This program was developed in 1986.

This program was written by S. W. Petrick and C. L. Cagle of Caltech for **NASA's Jet Propulsion Laboratory**. *NPO-17179 /TN*

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NASA Tech Brief
National Aeronautics and Space Administration
Langley Research Center, Hampton, Virginia

Licensing Opportunity

Portable Test and Monitoring System for Wind-Tunnel Models

Model instrumentation can be tested in or out of the wind tunnel.

A portable system has been developed to test and monitor the instrumentation used in wind-tunnel models. The system is currently in use at the Langley Research Center 16-ft (4.9-m) wind tunnel.

This system has the capability of monitoring balance readouts on all six wind-tunnel model components: normal, axial, pitch, roll, yaw, and side. It can be used for checking thermocouples and electrical leads for continuity and for leak-checking pressure transducers. It was developed as a completely portable and self-contained unit that can be moved to the location where the work is being performed.

The primary benefits realized with the portable test and monitoring system are associated with a saving of time. The models used in this major wind-tunnel facility are very complex. Previously, about 30 percent of the facility occupancy time was devoted to model calibration and buildup. Without this system, a large portion of the pretest buildup of a wind-tunnel model cannot be conducted until the model is inserted into the tunnel and connected to the data-acquisition system, wasting valuable tunnel time.

With the full utilization of this portable equipment, a portion of the calibration and checkout work can be accomplished outside of the facility, shortening the time required for model installation. Because of these features, this system can be used for checkout during model buildup before the model is installed in the wind tunnel or for trouble-shooting model-instrumentation problems after the model is installed in the tunnel.

This work was done by Charles A. Poupard of **Langley Research Center**. *No further documentation is available.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Langley Research Center Refer to LAR-13405/TN

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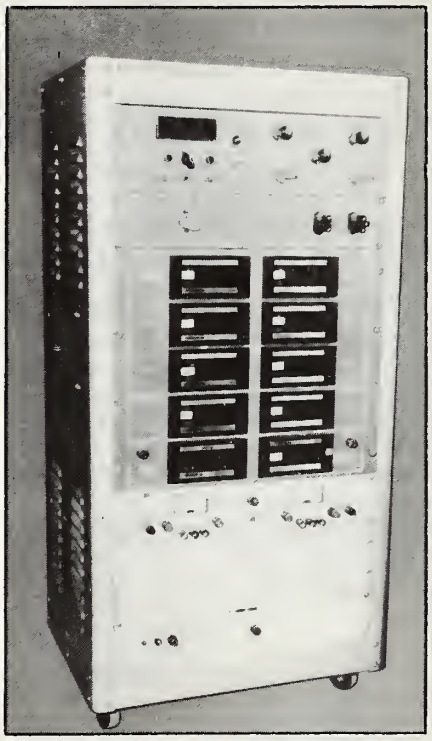

The **Portable System Is Self-Contained** and can be moved easily to the model, either before or after the model is installed in the wind tunnel. The system is 44½ in. (113 cm) high, 22 in. (56 cm) wide, and 17 in. (43 cm) deep and weighs 100 lb (45 kg).

FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD 21240; (301) 621-0100 Ext. 241*

REFER TO THE NUMBER LISTED AT THE END OF THIS ARTICLE

NASA Tech Brief
National Aeronautics and Space Administration

Licensing Opportunity

Water-Tunnel Flow Visualization With a Laser

Experimental conditions for effective visualization are determined.

A NASA Technical memorandum describes preliminary experiments in laser-enhanced flow visualization in a water tunnel. Aspects of the study include the required laser power, flow seeding, model preparation, and photographic techniques. The results of the study can assist potential users in the design and construction of similar equipment.

The optical components were assembled around and in a water tunnel with a vertical test section of 0.61 by 0.41 m. The flow channel was enclosed by transparent poly(methylmethacrylate). The light from a 4-W argon laser was passed through a glass rod that served as a cylindrical lens to expand the beam into a fan of light 1.6 mm thick.

By the horizontal or vertical alignment of the glass rod, the plane of the light fan could be oriented parallel to the channel axis for the visualization of longitudinal flow or perpendicular to the axis to give a cross-sectional view of the flow. The fan was scanned along or across the model in the test section by moving the box containing the laser and its associated optics.

Varlous flow-seeding media were tried, including dyes that fluoresce under the laser radiation, the particles that naturally accumulate in the system, diatomaceous earth, glitter, and aluminum dust. Three test models were used: one of the Space Shuttle orbiter, one of the AV-8 Harrier airplane, and an ogive/cylinder/trailing-disk body. The Harrier engine intake was simulated by suction into the inlets, and the exhaust was represented by the ejection of water and dye through the outlets. The models were painted and marked in different ways to find which color scheme was most easily observable.

The illuminated, seeded flow was recorded by video techniques and by a 35-mm camera on color film. Some experiments were also conducted with black-and-white film, but color film was used predominantly because color prints were regarded as the most useful for documentation.

The experiments led to the following conclusions regarding the conditions that contribute to effective flow visualization:

- Of the dyes tested, the best is fluorescein sodium at a concentration of about 250 mg/L.
- With only the naturally occurring particles entrained, the flow could be seen by eye, but not enough light was reflected for good photography. Most of the deliberately entrained particulates formed clumps, but aluminum powder dispersed well when liquid soap was added to reduce the surface tension.
- Though particles degrade the pumps and filters, they give a more accurate visualization than do jets of dye, which can distort the flow.
- The models and flow are best seen when the models are painted medium gray with a matte finish. Reference marks on the models should be drawn with a grease pencil for high visibility and for ease of application and erasure.
- The laser power should be about 270 mW.
- With ASA 1,000 color film and a lens of aperture f/1.2, the shutter time should be 1/250 s for streamwise flow and 1/80 to 1/60 s for crossplane flow.
- Both f/1.6 and f/1.4 lenses work well for video recording.

This work was done by Christine Beckner and Robert E. Curry of **Ames Research Center**. *Further information may be found in NASA TM-86743 [N86-11206/NSP], "Water Tunnel Flow Visualization Using a Laser."*

A copy may be purchased from the National Technical Information Service, Springfield, Virginia 22161.

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Ames Research Center. Refer to ARC-11698/TN

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Environmental Science & Technology

388 Hazardous Gas Dispersion Model

389 Marine Pollutant Trajectory Model

Software

390 Prediction of Oil Spill Transport

Testing & Instrumentation

391 Monitoring Microbial Pesticides (Licensing Opportunity)

NOAA Technology Brief

National Oceanic and Atmospheric Administration
National Ocean Service
Office of Oceanography and Marine Assessment

Hazardous Gas Dispersion Model

A Gaussian atmospheric dispersion model has been developed for response to chemical spills that release hazardous gases. Called ALOHA for Areal Locations of Hazardous Atmospheres, the model calculates downwind, ground-level concentrations; crosswind spread; and time of travel for both continuous and instantaneous releases of chemicals.

ALOHA has its own chemical library that can be modified or expanded. It also has a user-defined option and a puddle model option for source-strength input and algorithms. The user can also input meteorologic parameters into ALOHA or hook up to real-time field measurements from a deployed, portable meteorological station known as SAM (Station for Atmospheric Measurements). SAM collects data on wind speed and direction, temperature, and incoming solar radiation, and then transmits the data to ALOHA.

Dr. Jerry Galt of NOAA's Hazardous Materials Response Branch developed ALOHA for operation on an Apple MacIntosh computer.

Additional information about ALOHA can be obtained from NOAA ORTA, SPC, Room 307, Suitland, Maryland 20233. Telephone: (301) 763-4240.

87/NOS/024

NOAA Technology Brief

National Oceanic and Atmospheric Administration
National Ocean Service
Office of Oceanography and Marine Assessment

Marine Pollutant Trajectory Model

An interactive computer program is available for pollutant trajectory modeling in the marine environment. Called the On-Scene Spill Model (OSSM), it has been used to predict the trajectories of more than 500 spills of oil and hazardous materials in waters around the world.

The model projects the trajectory of a spilled pollutant based on analysis of properties of the spilled substance, oceanographic and meteorological observations, statistical climatological simulations, bathymetry, coastal outlines and shorelines descriptors, numerical circulation models, and other environmental data. It can be run in normal mode to predict the path of a pollutant, or in a receptor mode to predict potential threat zones from which pollutants could travel to receptor sites.

When run in normal mode, OSSM output consists of maps showing pollutant distribution over time. When run in receptor mode, OSSM output consists of threat zone maps showing a probability distribution of pollutant origin, as well as maps delineating probability distributions of time of travel.

Dr. Jerry Galt of NOAA's Hazardous Materials Response Branch developed OSSM for operation on any computer that can use standard FORTRAN.

Additional information about OSSM can be obtained from NOAA ORTA, SPC, Room 307, Suitland, Maryland 20233. Telephone: (301) 763-4240.

87/NOS/027

US Army Corps of Engineers
Cold Regions Research & Engineering Laboratory
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PREDICTION OF OIL SPILL TRANSPORT

PROBLEM

Oil spills in rivers and lakes can cause severe environmental damage by contaminating the water and damaging the shoreline. Forecasting their movement is complicated. They can spread through advection of water currents and wind velocity and they can spread mechanically over the surface through gravity. Winter spills may come into contact with floating ice, which can have a large effect on their movement. Evaporation and dissolution can radically transform the mass and material properties of a spill. Spills which contact the shoreline may remain and a portion may be released back into the water with time.

SOLUTION

An oil spill model has been developed that provides the ability to simulate:

- The advection of a spill by water currents and wind velocity.
- The mechanical spreading of a spill due to gravity, viscous, and surface tension effects.
- The effect of evaporation and dissolution on the spill volume.
- Open water and ice-covered water conditions.
- The interaction of a spill with the shoreline.

The model forecasts the movement of the spill on a two-dimensional grid that is superimposed over the river or lake system. The total spill is represented by a large number of parcels, and the movement of each parcel is determined. The movement of instantaneous or continuous spills can be modeled.

The model output consists of maps showing the location of the spill at a user-selected time interval; river or lake boundaries and landmarks are labeled. Three different spill constituents are currently available: gasoline, bunker C oil, and No. 2 fuel oil. Others can easily be implemented. A menu-driven version of the model is available on a desktop PC which produces high-resolution maps. The operator has the ability to zoom in on any specified region for more detail. The program is currently set up for the Great Lakes connecting channels, but it is written in modular form and can be adapted to any waterway or lake.

CONTACT

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United States Department of Agriculture

Research Technology
Agricultural Research Service

Monitoring Microbial Pesticides

BTI, a crystal protein that has been isolated from the bacterium *Bacillus thuringiensis israelensis,* is a recent arrival on the commercial pesticide market. This bacterially produced substance is deadly to the larvae of certain biting insects such as mosquitoes, black flies, midges, and horn flies.

Although the substance effectively kills insects, scientists were unable to agree on how—or why—it works. To help answer these questions, an ARS scientist invented an assay method that uses a biological-chemical tracer to measure the chemical's presence.

Derived in part from mouse spleen cells, the tracer is designed to chemically highlight the insecticide's path as it is taken up by the organism.

This invention can help manufacturers of the insecticide attain better quality control, product standardization, and measurement. It is also expected to assist researchers in development of new BTI-based products.

For technical information, contact Kevin B. Temeyer, P.O. Box 232, USDA-ARS Livestock Insect Laboratory, Kerrville, TX 78029-0232.

"Monoclonal Antibodies to Crystal Protein of *Bacillus thuringiensis* subspecies *israelensis*."

For Additional Information:

Inquiries concerning rights for commercial use of this invention should be addressed to

Office of Federal Patent Licensing
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Room 13R, NTIS
Springfield, VA 22161
(703) 487-4738

Refer to Patent Application 7-050,451

Manufacturing, Machinery, & Tools

392 Studies of Oxide Dispersion Strengthening of Aluminum Alloys

393 Vacuum Plasma Spray Overlay Coatings

394 Contamination-Free Electrical-Discharge Machining — Debris are swept into the electrode by the flow of coolant. (Licensing Opportunity)

395 Pin Inserts for Plug Welds — Leakage through minute cracks is eliminated.

396 Protective Coating for Laser Drilling of Silicon — Sodium silicate prevents spattered silicon from fusing with surrounding material.

397 Tool Removes Arc-Light Reflectors — Self-clamping reflectors are easily removed from welding torches. (Licensing Opportunity)

Testing & Instrumentation

398 Optoelectronic Proximity Sensor Finds Edges — Seams are tracked for automatic control of welding. (Licensing Opportunity)

399 Holding X-Ray Film Inside Ducts — A simple, easy-to-use device speeds inspection. (Licensing Opportunity)

Other Items of Interest

400 Effect of Manufacturing Processes on Structural Allowables

404 Active-Substrate Brazing Process

Studies of Oxide Dispersion Strengthening of Aluminum Alloys

A summary of significant results of a 5-year study of oxide dispersion strengthening conducted at Stanford University under an AFOSR grant is contained in a report. Several of the conclusions from this work will be of interest to those engaged in studies directed toward improving the high temperature properties of aluminum-base alloys by means of dispersion hardening. These are presented below:

- Based on work conducted on aluminum-magnesium oxide dispersion strengthened alloys, it appears that solute strengthening cannot be combined effectively with oxide dispersion strengthening. At high temperatures, the oxide dispersion resulted in significant increase in creep strength. However, at intermediate temperatures, the dispersion free alloys.

- Companion studies conducted with Al-Fe-Ce dispersion containing alloys showed these alloys to be much stronger than the oxide dispersion strengthened Al-Mg alloys at low and intermediate temperatures, but weaker at high temperatures. The latter behavior was attributed to twinning of the intermetallic particles in the Al-Fe-Ce alloy at high temperatures.

- Alloys with superior properties could be produced by introducing an oxide (or carbide) dispersion into the Al-Fe-Ce alloy by mechanical alloying. The presence of extremely refractory particles is apparently required to achieve high temperature strength.

FOR ADDITIONAL INFORMATION: A copy of the report is available from NTIS, Springfield, VA 22161; (703) 487-4600.
NTIS order number: AD-A173356/7/NAC
Price code: A03

Vacuum Plasma Spray Overlay Coatings

The objective of the overlay protective coatings project, performed by Pratt & Whitney, was to establish and optimize vacuum plasma spraying. The process was needed for manufacturing superalloy blade and vane high pressure turbine components and for recoating Air Force advanced gas turbine engines during overhaul. Because these engines operate under severe conditions, such as very high combustor exit temperatures, there are stringent demands on the materials used for turbine airfoils. Use of the latest developments in heat-resistant materials has provided airfoil tensile and creep strengths to match these requirements. However, modern turbine airfoils are frequently life limited by surface environmental resistance, a problem not assisted by the seemingly inverse relationship between alloy strength and oxidation or corrosion resistance. This life limitation has emphasized the necessity for protective surface coatings.

The quality and durability of the popular MCrAlY coatings produced by the vacuum plasma spraying process have been found to be superior to those produced by other plasma spray processes. The vacuum process also employs less expensive equipment and thus processing costs, than the popular electron beam physical vapor deposition process. In addition, it allows almost complete composition flexibility because any composition that can be fabricated into sprayable powder can be deposited. Consequently, it provides a means, with near-term production readiness, for depositing the latest advances in turbine airfoil coatings.

The technical effort was divided into four phases to accomplish the following tasks: 1) evaluate optimized vacuum plasma spray process variables, which affect process control and coating morphology, 2) verify optimized process parameters through extensive laboratory and engine testing, 3) integrate the parameters into an adaptively controlled demonstration microprocessor interfaced coating system, and design and construct the necessary software programming and computer hardware interfacing to provide sufficient process automation for coating production quantities of turbine engine hardware, and 4) demonstrate and verify the process.

Appropriate quantities of advanced gas turbine engine hardware were coated for subsequent engine testing. In addition, process specification and quality assurance plans were established. To provide data for engine qualification of the coating process, a post engine test evaluation was performed, followed by a cost analysis.

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Refer to contract F33615-80-C-5051

NASA Tech Brief
National Aeronautics and Space Administration

Licensing Opportunity

Contamination-Free Electrical-Discharge Machining

Debris are swept into the electrode by the flow of coolant.

Marshall Space Flight Center, Alabama

The contamination of parts by electrical-discharge machining (EDM) can be almost completely eliminated by reversing the flow of coolant. EDM normally produces contamination from electrode wear and workpiece erosion. When the direction of flow of coolant in the electrode is away from the workpiece instead of toward it (see figure), contaminant particles are whisked away through the hollow EDM electrode.

Use of CCl_2F_2 as the coolant instead of the usual water or oil further reduces contamination. The CCl_2F_2 efficiently cools the electrode and electrically insulates it from the workpiece until a sufficiently high voltage is reached. Unlike water or oil, however, the CCl_2F_2 is completely volatile and leaves no contaminating residue on the workpiece. The CCl_2F_2 is used in the saturated-vapor state.

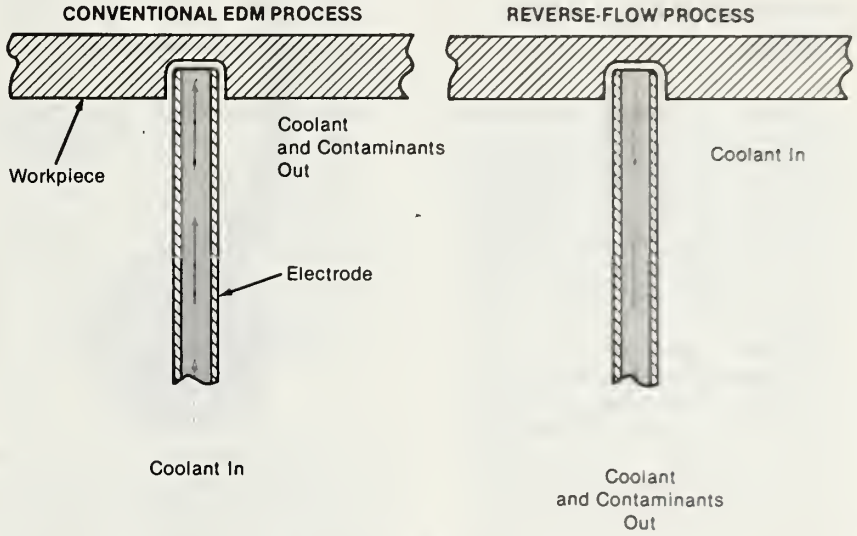
In a demonstration of the reverse-flow process, holes of 0.050 in. (1.27 mm) in diameter were drilled through Inconel* 718 samples 0.125 in. (3.18 mm) thick. Four sets of samples were machined with repeatable results. The vapor pressure of the CCl_2F_2 varied from 40 to 90 psig (283 to 627 kPa). The brass EDM electrode had a 0.045-in. (1.14-mm) outside diameter and a 0.030-in (0.76-mm) inside diameter. No contamination was visible.

*Inconel is a registered trademark of the Inco family of companies.

This work was done by Mark G. Schmidt of Rockwell International Corp. for **Marshall Space Flight Center**.

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center.

Refer to MFS-29197/TN



The **Flow Is Reversed** from the usual direction so that the coolant carries contaminants out through the passage in the electrode. The coolant for reverse flow is pressurized dichlorodifluoromethane vapor.

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REFER TO THE NUMBER LISTED AT THE END OF THE ARTICLE

NASA Tech Brief
National Aeronautics and Space Administration

Pin Inserts for Plug Welds

Leakage through minute cracks is eliminated.

Marshall Space Flight Center, Alabama

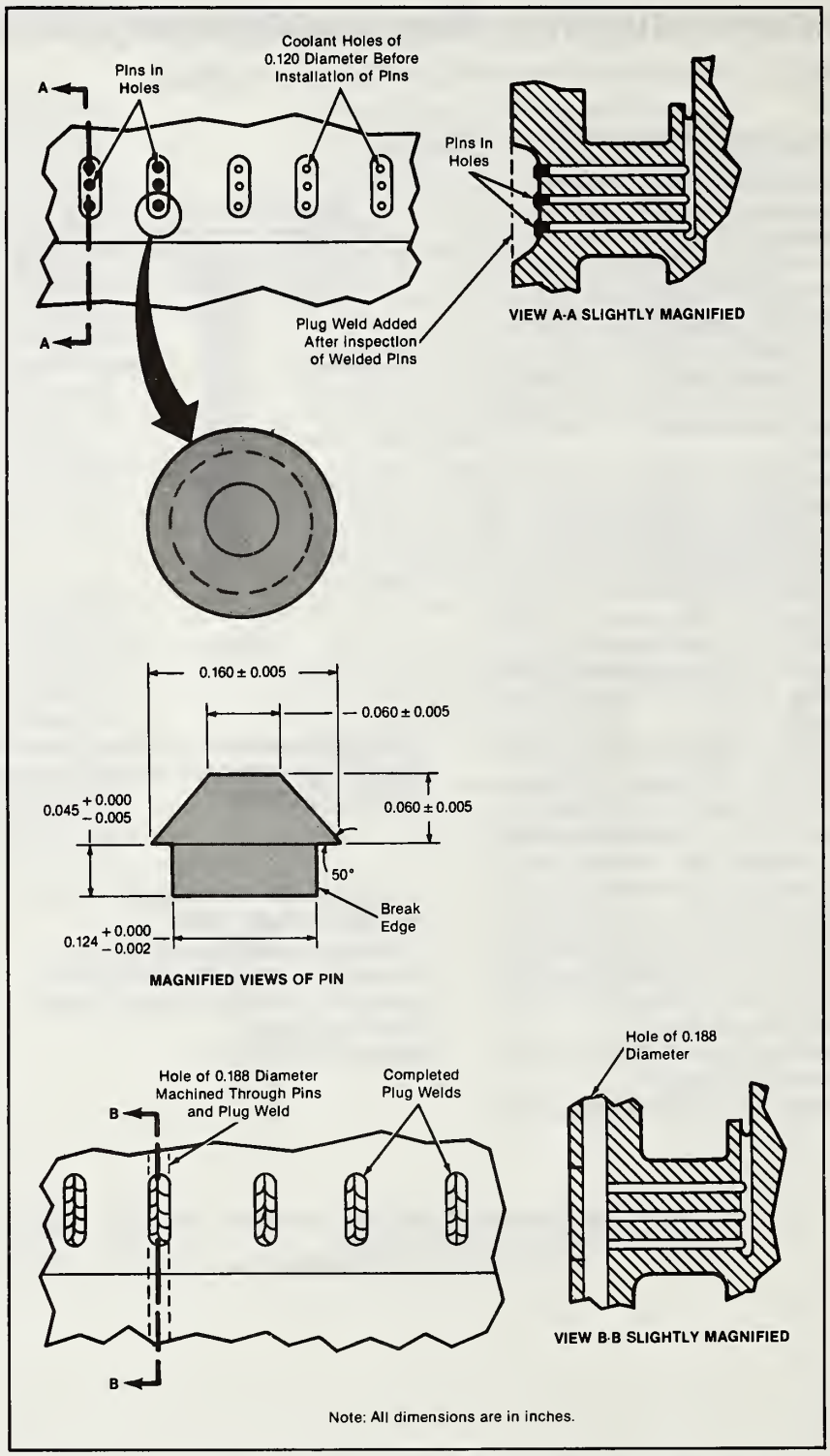
Expendable pin inserts solve a chronic problem of cracking in and near plug welds. Previously, machined coolant holes in Inconel* were sealed by gas/tungsten arc welding. However, the welded parts frequently contained cracks that became evident in radiographic inspection. The parts had to be reworked and sometimes discarded.

With the expendable-pin method, cracks are nearly eliminated. Inconel* 718 pins are machined to press-fit into the coolant holes, which are 0.120 in. (3 mm) in diameter and arranged in slots in groups of three. The pins are electron-beam-welded in place. (The welding parameters are determined by experimenting on scrap material.)

The quality of the pin welds is checked by liquid-penetrant and radiographic inspection. If the welds pass these tests, the pins are ground flush to the adjacent surfaces. The slots are then filled by gas/tungsten arc welding. The welds are subjected once more to liquid-penetrant and radiographic inspection, which shows that the slots are 90 to 100 percent free of defects. Finally, a hole 0.188 in. (4.78 mm) in diameter and perpendicular to the coolant holes is machined along the slot, removing the pins.

*Inconel is a registered trademark of the Inco family of companies.

This work was done by Michael Penninger of Rockwell International Corp. for **Marshall Space Flight Center**. *No further documentation is available.*
MFS-29193/TN



Electron-Beam-Welded Pins reinforce the material around the coolant holes during plug welding and subsequent remachining. The pins are removed in the final machining of the 0.188-in.-diameter hole.

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NASA Tech Brief
National Aeronautics and Space Administration
NASA's Jet Propulsion Laboratory, Pasadena, California

Protective Coating for Laser Drilling of Silicon

Sodium silicate prevents spattered silicon from fusing with surrounding material.

The spattering of silicon during laser drilling or machining of a silicon wafer can be prevented from damaging the surrounding wafer or mask by forming a protective coating on the wafer before drilling or machining. To be effective in preventing such damage, a protective coating must have the following properties:

- Be easy to apply;
- Not react with the substrate or mask;
- Not be melted, penetrated, or destroyed by the spattered material;
- Not interfere with laser drilling or machining; and
- Wash off along with any spatters without damage to the mask or wafer.

The best coating materials found thus far come out of aqueous solutions as glasses. These include borates, phosphates, and silicates of the alkali metals. One material that can be applied satisfactorily is a dilute aqueous solution of "stabilized" sodium silicate (common "water glass"). The solution is stabilized by equilibrating it with powdered silica so that any excess alkali (which might react with the silica mask on the silicon wafer) is removed. Tests have not been run to determine whether the stabilization step is essential.

The sodium silicate solution can be applied to the wafer by dipping and draining or by spinning; presumably, application by spraying would also work. When dried in an oven, the solution leaves a thin coating of sodium silicate glass.

In a test, silicon wafers were partly coated with solutions of sodium metasilicate and sodium polysilicate and dried at 250 °C. A ruby laser was used to drill 0.003-in. (0.08-mm) holes in the coated and uncoated portions. The coatings were then removed by soaking in hot water for a few hours. The areas that had been coated were free of spatters. However, the coatings reacted with the laser beam to form rims of sodium silicate around the holes.

This work was done by Paul J. Shlichta of Caltech for **NASA's Jet Propulsion Laboratory**. *NPO-17148 /TN*

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REFER TO THE NUMBER LISTED AT THE END OF THE ARTICLE

NASA Tech Brief
National Aeronautics and Space Administration
Marshall Space Flight Center, Alabama

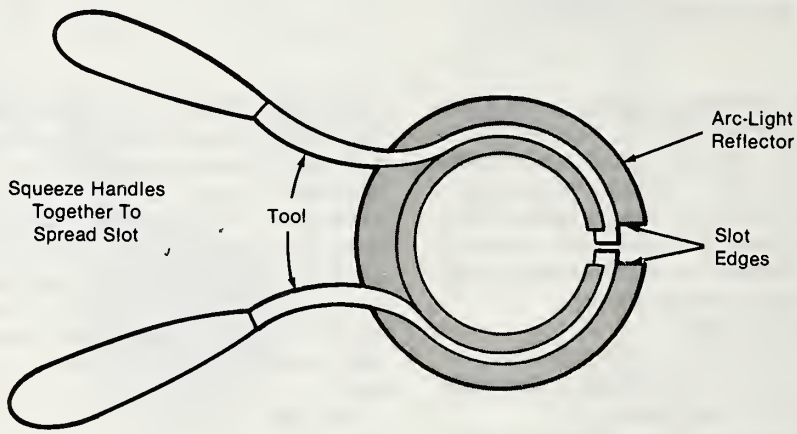
Licensing Opportunity

Tool Removes Arc-Light Reflectors

Self-clamping reflectors are easily removed from welding torches.

A new tool makes the installation, adjustment, and removal of self-clamping arc-light reflectors on welding torches easy and simple. Normally, such a reflector clamps so tightly onto the end (gascup) of a welding torch that it is difficult to remove with bare hands. Usually, a screwdriver is wedged into a slot on the reflector to spread the clamping portion: this is an awkward operation that occasionally results in damage to the slot edges.

The tool, shown in the figure, consists of two arms that reach around from the back of the torch. A lip on each arm hooks into the slot of the arc-light reflector clamp. When the handles of the tool are squeezed together, the slot is spread, enabling easy installation, adjustment, or removal of the reflector without disassembly of the welding apparatus. At the same time, the tool grips the arc-light reflector firmly so that it can be positioned.



When the Handles of the Tool are squeezed together, the clamp of the arc-light reflector is spread, making the reflector easily removable without risk of damage.

This work was done by Stephen S. Gordon of Rockwell International Corp. for **Marshall Space Flight Center**. *No further documentation is available.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center Refer to MFS-29235 /TN

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REFER TO THE NUMBER LISTED AT THE END OF THE ARTICLE

NASA Tech Brief
National Aeronautics and Space Administration
NASA's Jet Propulsion Laboratory, Pasadena, California

Licensing Opportunity

Optoelectronic Proximity Sensor Finds Edges

Seams are tracked for automatic control of welding.

An optoelectronic system based on a relatively simple array of optical proximity sensors locates the edge of a plate. The system can be used to control automatic production machinery — for example, to locate spot welds at the correct lateral position with respect to the seam between two overlapping metal plates or sheets. The system follows curved seams as well as straight ones, and neither special control programming nor precise initial positioning of a workpiece is necessary for accurate tracking of a seam.

Facing the workpiece is an array of optoelectronic proximity sensors (see Figure 1) in a line across the seam. Each proximity sensor is calibrated for use with the particular workpiece material and configuration, so that the output of each sensor can be used to determine the distance to the workpiece surface.

Each sensor is sampled in turn. The light-emitting diode is turned on, and the output of the detecting photodiode is measured. The digitized measurements are used to locate the exposed edge of the workpiece: the system computer finds the lateral position that corresponds to a previously calibrated sensor-output value between the values for the flat surfaces on either side of the edge. In effect, this amounts to a crude form of image analysis, in which the field of view of each sensor constitutes a picture element. For high definition of the position of the edge (high resolution), the sensor array should be dense and the fields of view should abut or overlap slightly.

Although the light-emitting diodes and detecting photodiodes could be mounted in the sensing head as in Figure 1, it would be better to remove them from the vicinity of the weld to reduce electromagnetic interference. Therefore, in a practical system, the diode pairs are mounted on circuit cards with other electronic circuits and connected through glass optical fibers to the lens array in the sensing head. This arrangement also facilitates tracking by reducing the size and mass of the sensing head.

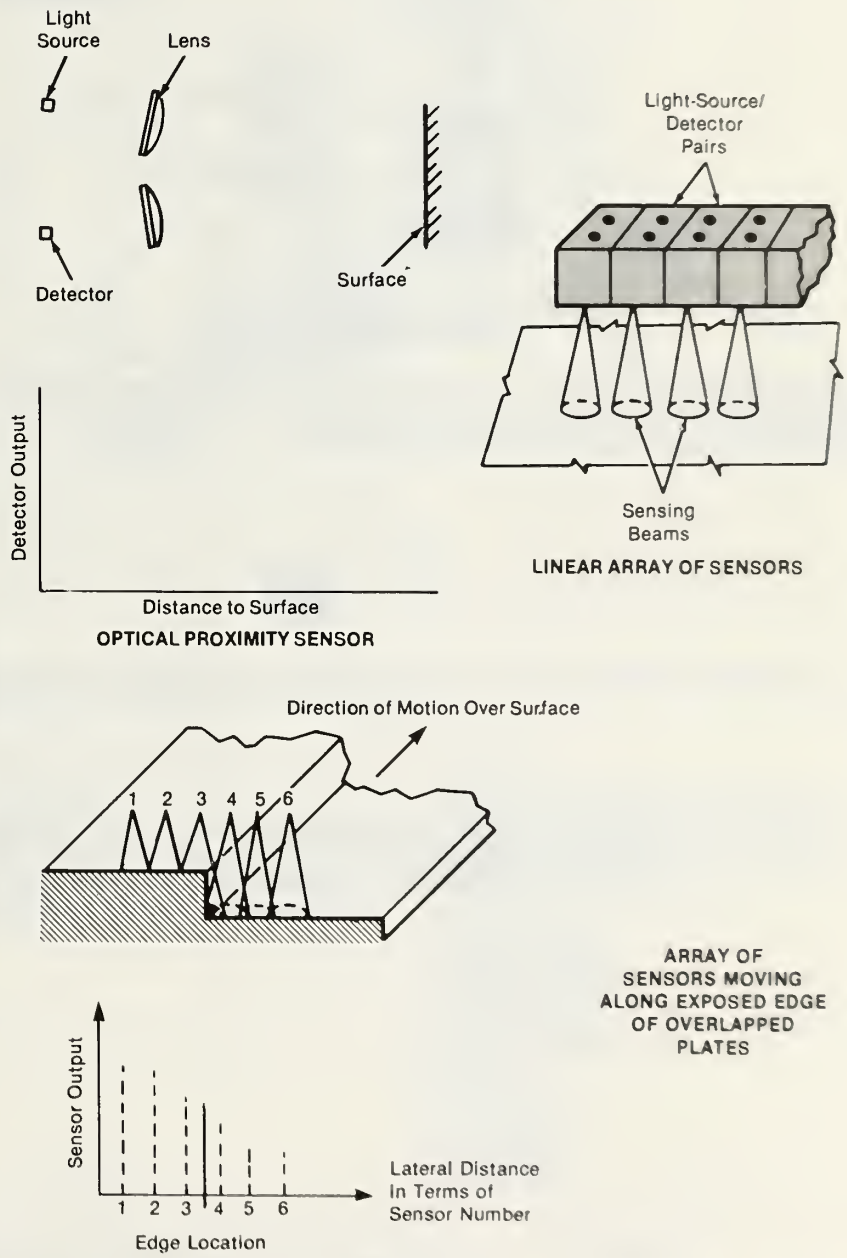

Figure 1. In an **Optoelectronic Proximity Sensor**, the signal from a light-emitting diode is reflected by a surface and detected by a photodiode. For a given surface viewed perpendicularly or at a fixed angle, the known dependence of the photodiode output with distance can be used to determine the instantaneous distance to the surface. A linear array of such sensors can thus be used to obtain a rough profile of the surface along the axis of the array.

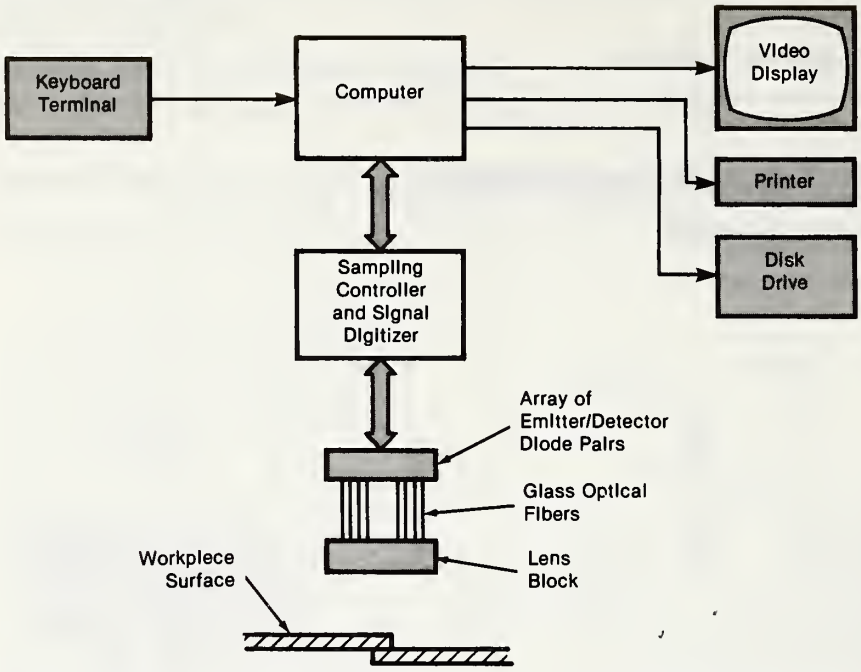

Figure 2. The **Optoelectronic System** processes the outputs of the linear array of sensors to locate the exposed edge. In this configuration, the sensing head is separated from the diode pairs and optically reconnected to them through fiber optics.

Other subsystems and the overall system configuration are shown in Figure 2. Through a standard keyboard, the operator instructs the computer in the specifics of the task. The computer controls the sampling of the proximity sensors and displays the processed outputs in sequence on a video screen. The results of the sensor scans can also be sent to a printer or saved on a magnetic disk.

This work was done by Antal K. Bejczy of Caltech for **NASA's Jet Propulsion Laboratory.**

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use of this invention should be addressed to

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REFER TO THE NUMBER LISTED AT THE END OF THIS ARTICLE

NASA Tech Brief
National Aeronautics and Space Administration
Marshall Space Flight Center, Alabama

Licensing Opportunity

Holding X-Ray Film Inside Ducts

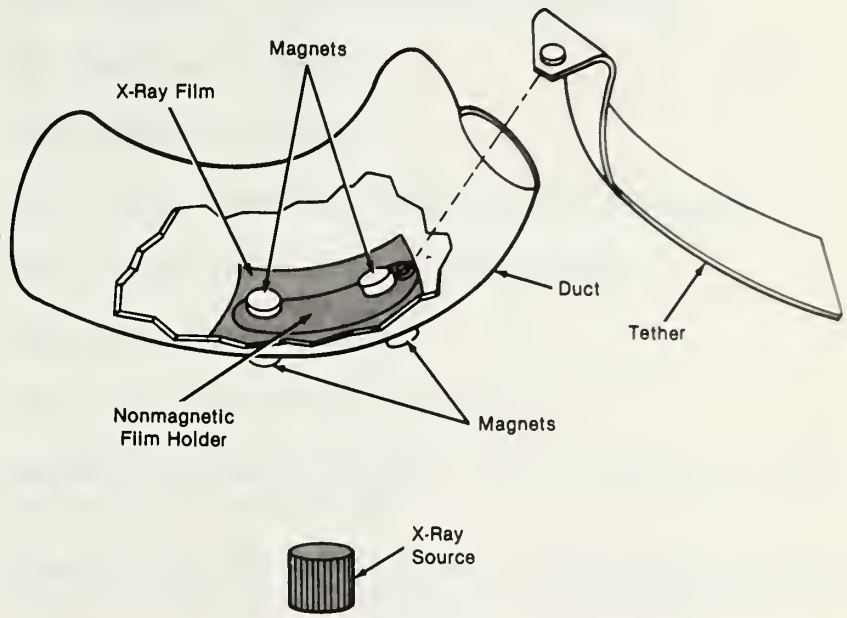
A simple, easy-to-use device speeds inspection.

Radiographic inspection of welds in the walls of nonmagnetic ducts is made easy by a new film holder. The holder enables the quick and accurate positioning of x-ray film inside a duct and presses the film securely against the inner wall for minimum image distortion and maximum sensitivity to irradiation by an x-ray source outside the duct.

Two pairs of opposed magnets are used to position the film (see figure). The magnets are strong, each having a holding force of 8 lb (36 N). Each is a disk of rare-earth/cobalt with a diameter of 0.75 in. (19 mm) and a height of 0.285 in. (7.2 mm). A pair of disks is bonded to a flexible, nonmagnetic film holder.

For an x-ray inspection, film is taped to the holder and placed inside the duct. The second pair of magnets is placed on the outside wall and oriented so that their poles attract the magnets on the holder, pressing the film tightly against the inside wall so that it conforms to the curvature of the duct. The exterior magnets indicate the position of the interior magnets and, therefore, of the holder and film. The holder can be repositioned easily by pulling its tether; the outside magnets will follow the inside ones.

The use of the holder avoids the need for mirrors and borescopes, saves time, and eliminates guesswork in the positioning of the film. It reduces inspection time by at least 90 percent.



X-Ray Film Inside a Duct is held by interior and exterior magnets. The tether is used to move the holder and to retrieve it from inside the duct.

This work was done by Ronald V. Bulthuis and Darryl Pierce of Rockwell International Corp. for **Marshall Space Flight Center**. *No further documentation is available.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center Refer to MFS-29218. /TN

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REFER TO THE NUMBER LISTED AT THE END OF THE ARTICLE

Materials

400 Effect of Manufacturing Processes on Structural Allowables

401 Effects of Plastic Bead Paint Removal on Properties of Aircraft Structural Materials

402 Fatigue Properties of Premium Quality Aluminum Castings

403 Indentation Damage in Ceramics

404 Active-Substrate Brazing Process

405 High-Temperature Corrosion of Silicon Carbide by Alkali Halides

406 NDE (Nondestructive Evaluation) of Adhesive Bonds

407 NMR Images of Solids Produced

408 Process Developed for Making Superconductors

409 Advances in Thermoelectric Materials — Rare-earth chalcogenides and boron-rich borides show promise.

410 Ceramic Adhesive for High Temperatures — The fused-silica/magnesium-phosphate adhesive resists high temperatures and vibrations.

411 Degradation of Reflectors and Dielectrics — Terrestrial and orbital effects are described.

412 Glass-Bead Blasting Alters Antenna Surface — Thermal-emissivity properties are improved, and focal length is adjusted.

413 Polyphenylquinoxalines Containing Alkylenedioxy Groups — Better processability is achieved through the lowering of glass-transition and melt temperatures. (Licensing Opportunity)

414 Thermosetting Fluoropolymer Foams — Uses include coatings, electrical insulation, and structural parts. (Licensing Opportunity)

Software

415 ICAN: Integrated Composites Analyzer — This program calculates macromechanical, micromechanical, and related environmental effects.

416 Laminate-Moisture-Analysis Computer Program — The diffusion and the deleterious effects of moisture can be predicted.

Testing & Instrumentation

417 Slow Neutron Reflectometer (POSY II) — New application of neutron reflection techniques measures interdiffusion of polymers.

Effect of Manufacturing Processes on Structural Allowables

The utilization of new materials and manufacturing processes for advanced aircraft applications is often hampered by the lack of sufficient comparative mechanical property data. DoD and FAA regulations require that design allowable properties be acceptably supported by data available in MIL-HDBK-5, or by a statistically significant quantity of test data. A recent study completed by Battelle Columbus Division for AFWAL was aimed at alleviating this problem for three common superalloy materials, including solution treated and aged Inconel 718 bar, annealed Inconel 625 sheet, and annealed Inconel 625 bar. While these three materials are included in MIL-HDBK-5, the mechanical property data available is limited to ultimate tensile and tensile yield strengths. In addition to these properties, the Battelle study provides data for elongation, tensile modulus, compressive yield strength, compressive modulus, ultimate shear strength, ultimate bearing strength, yield bearing strength, and fatigue properties. Triplicate measurements are reported for each property, except fatigue, measured in two grain directions for a variety of bar diameters (2 to 4 inches) and sheet thicknesses (0.05 to 0.25 inch). Unnotched and notched, $K_3 = 3$, axial-stress fatigue tests were performed at three stress ratios, R = -0.5, R = 0.1, and R = 0.5, using 0.75-inch-diameter longitudinal bar specimens and 0.093-inch-thick transverse sheet specimens. Table 1 shows the range of mechanical properties reported for each material.

Table 1. Range of Mechanical Properties

Mechanical Property	Solution Treated and Aged Inconel 718 Bar	Annealed Inconel 625 Bar	Annealed Inconel 625 Sheet
Ultimate Tensile Strength, ksi	187 – 212	115 – 139	126 – 139
Tensile Yield Strength, ksi	155 – 183	56 – 79	59 – 75
Elongation, percent	21 – 26	36 – 59	44 – 53
Tensile Modulus, 10^3 ksi	23 – 31	22 – 35	26 – 31
Compressive Yield Strength, ksi	171 – 191	56 – 77	62 – 79
Compressive Modulus, 10^3 ksi	30 – 32	24 – 29	29 – 31
Ultimate Shear Strength, ksi	130 – 139	77 – 91	109 – 121
Ultimate Bearing Strength (e/D = 1.5), ksi	325 – 352	212 – 222	209 – 236
Bearing Yield Strength (e/D = 1.5), ksi	232 – 267	84 – 114	97 – 120
Ultimate Bearing Strength (e/D = 2.0), ksi	418 – 451	213 – 282	276 – 309
Bearing Yield Strength (e/D = 2.0), ksi	280 – 310	103 – 135	122 – 150

FOR ADDITIONAL INFORMATION: A copy of the report is available from NTIS, Springfield, VA 22161; (703) 487-4600.
NTIS order number: AD-A-176232/7/NAC
Price code: A05

Effects of Plastic Bead Paint Removal on Properties of Aircraft Structural Materials

Paint coatings are used extensively to perform multifunctional purposes on virtually all aircraft systems and associated support equipment including protection against corrosion, camouflage, thermal protection, and erosion resistance. During the life of the weapon systems, the coatings require removal for a variety of reasons from replacement of worn coatings to changes in camouflage schemes. Removal of chemically resistant coatings used on weapons systems is labor intensive and generally requires the use of strongly activated chemical strippers. However, in recent years paint-removal technology has not kept pace with the rapid advances of new polymeric resins in the coatings industry. However, as coatings transitioned from alkyds and nitrocelluloses to epoxies, polyurethanes, and fluoropolymers, the traditional solvent-type strippers were no longer effective removal agents for the new polymer coatings. In contrast to the earlier alkyd and acrylic nitrocellulose coatings which, generally, were functional for only one to two years, the presently used coatings have a life expectancy of five to seven years due to their excellent environmental, erosion, and fluid resistance.

The approach taken by the chemical manufacturers to provide strippers for the presently used coatings has been to add an "activator" to the traditional solvent-type strippers. Phenols and amines are the commonly used activators. However, these strippers do not effectively or economically remove the epoxy and polyurethane coatings. Removal can require as many as five applications of stripper together with aggressive mechanical agitation using powered and hand brushing. Although the phenol activated strippers are more effective than the amine activated strippers, the fact that the phenols are not biodegradable can cause water pollution problems. Also, hexavalent chromium compounds, which are used in the strippers as corrosion inhibitors, further restrict the use of present strippers from an environmental viewpoint. In addition, organic matrix composites, such as graphite/epoxy, are now being used in aircraft structures. The same polymeric coatings are being applied to these composite components as those used on the metallic skins. Accordingly, chemical paint strippers cannot be used for paint removal from composite structures because of the high risk that they will chemically attack the organic matrix material.

Because of the above cited reasons, as an alternative to chemical paint stripping, considerable investigation of mechanical paint removal by abrasive blasting using various media (e.g., crushed corn cobs, glass beads, walnut shells, systetro diamond dust, garnet, dry-ice pellets, and high-pressure water) has been carried out with only limited success. Based on project work carried out at Ogden Air Logistics Center (ALC) an abrasive blasting process using plastic beads has been proposed for removing paint coatings from aircraft surfaces and component parts. During the prototype development of the plastic bead blasting process at the Ogden ALC using the F-4 aircraft, many concerns surfaced relative to the potential effects of the process on the physical and mechanical properties of metal and composite aircraft structural materials. Accordingly, an extensive evaluation of the effects of the plastic beam process, on selected aerospace structural materials was carried out at the Materials Laboratory at Wright Patterson Air Force Base (WPAFB), Ohio.

The results of the WPAFB evaluation of the plastic bead blasting paint removal process showed that it removed protective metal coatings such as aluminum cladding and anodized coatings from aluminum alloys and cadmium plating from steel components. Surface roughness values increased on clad aluminum alloys. Warpage as a result of surface cold working occurred on unsupported thin skin metal materials. The bond strength of thin-skin, adhesive-bonded structure was not affected. The process is less damaging to fatigue strength for 7075-T6 aluminum structure blasted at 60 psi nozzle pressure than at 38 psi nozzle pressure. Significant losses occurred in matrix-dominated properties as a result of plastic bead paint removal from graphite/epoxy structures; no significant reductions occurred in the fiber-laminated mechanical properties. Because of the losses in matrix-dominated properties, paint should not be removed from graphite/epoxy composite components using the plastic bead blast process.

Further work on the development and evaluation of the plastic bead paint removal process has been recommended by the WPAFB Material Laboratory to improve the process and also be better define its capabilities and performance for various applications. The Final Report contains detailed data and information on the test conditions and results obtained in the evaluation of the plastic bead blasting process for the removal of different paint coatings from a wide variety of aircraft structural surfaces.

FOR ADDITIONAL INFORMATION: A copy of the report is available from NTIS, Springfield, VA 22161; (703) 487-4600.
NTIS order number: AD-A165289/0/NAC
Price code: A08

Fatigue Properties of Premium Quality Aluminum Castings

The fatigue crack growth behavior of two premium quality aluminum castings, A201-T7 and A357-T6, were compared to those of the wrought alloy 7075-T76 in a study described in a recent report from the Air Force Wright Acronautical Laboratories. Center cracked panels for use in this study were obtained from a 1/2-inch-thick section of stepped plate castings. The casting method was not reported. 7075-T76 specimens were obtained from 0.2-inch thick plate. Tensile properties of the three materials are given in Table 2.

Table 2. Average Tensile Properties of A201-T7, A357-T6, and 7075-T76

Material	Yield Strength, ksi	Ultimate Tensile Strength, ksi	Elongation in 1-Inch Gage Length, percent
A201-T7	60	65	4.8
A357-T6	41	49	5.6
7075-T76	80	84	14

Fatigue tests were conducted using the fighter aircraft loading standard for fatigue (FALSTAFF) with three maximum stress conditions; 15, 20, and 25 ksi. All tests were conducted at room temperature and 5 Hz. The results of these tests, which should be considered as tentative since they were based on a relatively limited number of tests, are shown in Figure 1. As is apparent in this figure, A357-T6 showed greater crack growth resistance than either A201-T7 or 7050-T6. This material also exhibited the lowest tensile strength; see Table 2.

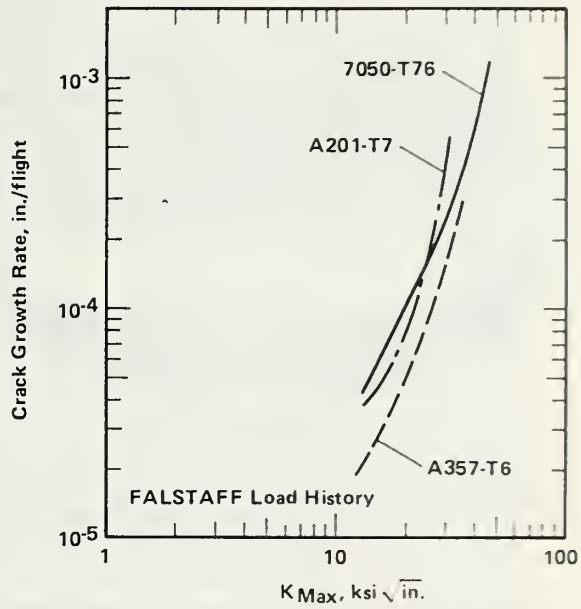

Figure 1. Fatigue Crack-Growth Rate in Spectrum Load Tests

FOR ADDITIONAL INFORMATION: A copy of the report is available from NTIS, Springfield, VA 22161; (703) 487-4600.
NTIS order number: AD-A176686/4/NAC
Price code: A03

NBS technology update

National Bureau of Standards
U.S. Department of Commerce
Gaithersburg, MD 20899

Indentation Damage In Ceramics

The basic processes of indentation damage in brittle ceramics has been studied. Attention was focussed on the roles of material crystallography and microstructure in determining the nature of the damage pattern. Microscopy techniques, particularly transmission electron microscopy, have been used to characterize the attendant deformation and fracture at Vickers indentation sites. Strength, toughness, and wear measurements have been carried out on polycrystalline materials to ascertain how the damage characteristics influence the ensuing mechanical properties. It is concluded that material microstructure can be a crucial factor in structural design with ceramics.

Transmission electron microscopy studies have been made on selected brittle ceramic materials, namely silicon, sapphire and silicon carbide. It was established that the deformation mechanisms are of a kind different from that of classical dislocation glide. In silicon, for instance, evidence was found for amorphization of the crystal structure in the central regions of the indentation sites. Also identified were twins, especially in sapphire. However, the predominant deformation mechanism in all these materials is a high-stress, shear-activated catastrophic slip process (somewhat akin to shear faulting in earthquakes). The importance of the deformation modes is that they act as precursors to cracking. There are strong rate effects associated with this attendant cracking; e.g. high-rate (impact) contacts suppress cracking.

FOR ADDITIONAL INFORMATION:

A full description of this activity is contained in a backup report which may be purchased from NTIS, Springfield, VA 22161; (703) 487-4650.

NTIS order number: Ad-A184686/NAC
Price code: A04

To discuss this effort further, contact Dr. Brian Lawn, Bldg. 223, Rm A335, National Bureau of Standards, Gaithersburg, MD 20899; (301) 975-5782.

Department of Energy

Technology Application

Oak Ridge National Laboratory

ACTIVE-SUBSTRATE BRAZING PROCESS

Key words: Ceramics; brazing; ceramic-metal joining; ceramic-ceramic joining

The active-substrate brazing process is an effective method for joining a partially stabilized zirconia (PSZ) to nodular cast iron (NCI). This development is significant because former attempts to braze these materials proved unsuccessful, and alternative methods for providing the necessary insulation against high temperatures (such as mechanical attachment or coating with ceramic powders) have not shown great promise. To join PSZ to NCI—a requirement for fabricating the ceramic piston cap used in some advanced diesel engine designs—a filler metal with high ductility, high joint strength, and low melting temperature is required. A low brazing temperature protects the properties of PSZ and NCI that high-temperature brazing would destroy.

Liquid metals used as filler material generally do not "wet" ceramic substrates unless special precautions are taken. In the active-substrate process, a material that promotes wetting is vapor coated onto the surface of the ceramic in a preliminary treatment designed to optimize surface reactivity and adhesion. In laboratory tests, an 11.2-cm PSZ disk was vapor coated with titanium, and an NCI disk was electroplated with copper. A transition layer of titanium (0.7 mm) was placed between two pieces of commercial filler metal (0.08 mm). Brazing took place in a vacuum furnace at 735°C (Fig. 1).

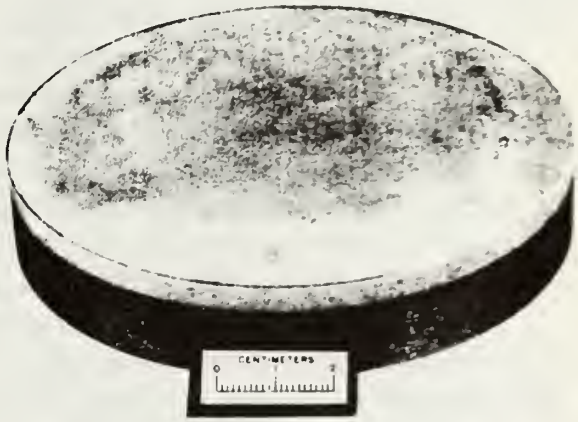

Fig. 1. A PSZ composite sample brazed to an NCI disk via the active-substrate brazing process.

The active-substrate process produced good bonding between PSZ and NCI. Application to commercial-sized components appears feasible. This process can be applied in various ways in addition to fabricating diesel piston caps:

- installation of other metallic components in diesel engines,
- attachment of ceramic turbine rotors to metallic shafts,
- attachment of ceramic wear pads,
- fabrication of bore seals for space power generators, and
- formation of joints involving cast irons to each other and to other metallic components.

U.S. patent No. 4,621,761 has been issued for the active-substrate brazing process.

Additional information:

Office of Technology Applications
Information Service
Martin Marietta Energy Systems, Inc.
P.O. Box X
Oak Ridge, TN 37831
Telephone: (615) 574-4192; FTS 624-4192

J. P. Hammond et al., "Indirect Brazing of Structural Ceramics for Uncooled Diesels," pp. 523-29 in *Proceedings of the 22nd Automotive Technology Development Contractors Coordination Meeting, Dearborn, Mich., October 29-November 2, 1984, P-155,* Society of Automotive Engineers, Warrendale, Pa., 1985.

M. L. Santella et al., "Zirconia to Cast-Iron Brazing for Uncooled Diesel Engines," pp. 235-41 in *Proceedings of the 23rd Automotive Technology Development Contractors Coordination Meeting, Dearborn, Mich., October 21-24, 1985, P-165,* Society of Automotive Engineers, Warrendale, Pa., 1986.

Department of Energy

Technology Application

Oak Ridge National Laboratory

HIGH-TEMPERATURE CORROSION OF SILICON CARBIDE BY ALKALI HALIDES

Key words: Recuperator; industrial furnace; flue gas; silicon carbide; alkali halides

Ceramic recuperators are used to preheat combustion air for industrial furnaces in which heat is recovered from flue gases. In some applications the air is preheated to about 1000°C with flue gases at 1200 to 1300°C. Recuperator tubes and other components are constructed of silicon carbide (SiC) ceramics because these materials have the necessary strength and resistance to thermal shock and oxidation at high temperatures. Exposure tests, however, revealed that SiC ceramics are susceptible to corrosion by certain industrial furnace atmospheres. In particular, halide compounds were suspected to have caused the deterioration. Therefore, a study was performed in a laboratory furnace to determine if HCl, NaCl, and NaF cause corrosion of SiC in oxidizing atmospheres.

Specimens were exposed to a synthetic combustion atmosphere (SCA) containing the halides at 1200°C for about 1000 h. The SCA, which consisted of the products of combustion of methane and 10% excess air, was about 13 wt % CO_2, 11 wt % H_2O, 74 wt % N_2, and 2 wt % O_2. The concentrations of halides, which were tested separately, were 0.6 wt % HCl and 0.1 wt % of either NaCl or NaF.

Exposure to an SCA that contained HCl caused negligible weight changes, similar to those occurring in air; however, SCAs that contained NaCl and NaF caused weight losses and significant surface recession beneath a glassy reaction product. Polished cross sections (Figs. 1 and 2) show the glassy reaction product on the surface of sintered alpha SiC and reaction-sintered SiC specimens. The reaction product, which had been molten at 1200°C, contained about 48 wt % Si and 3 wt % Na, the balance being mostly O_2. Tridymite (SiO_2), the only crystalline phase identified, might have formed during cooling. The material that deposited in the furnace tube downstream of the specimens contained NaCl or NaF and Si, indicating that a volatile Si compound formed during reaction. X-ray diffraction, however, failed to identify the silicon-containing compound.

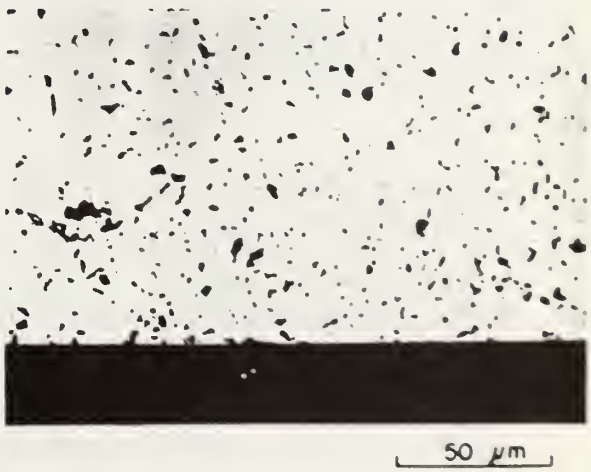

Fig. 1. Sintered alpha SiC exposed to an SCA containing NaCl at 1200°C for 1035 h (400×).

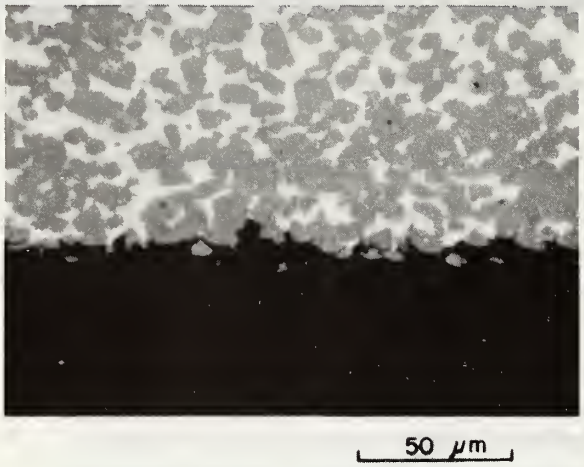

Fig. 2. Reaction-sintered SiC exposed to an SCA containing NaF at 1200°C for 986 h (400×).

These results show that SiC ceramics are not attacked by HCl but are attacked by NaCl and NaF in oxidizing atmospheres. Although the reaction mechanism is not yet clear, the evidence suggests that NaCl and NaF react with SiC to produce volatile Si compounds and $Na_2O \cdot xSiO_2$ ($x = 0.5, 1, 2$) compounds. The latter compounds, which are molten at 1200°C, allow enhanced diffusion of O_2 to the SiC, which oxidizes to SiO_2 and CO_2. These events are consistent with the weight loss, surface recession, and silicon-containing reaction product occurring in these experiments. These results show that alkali halides, the suspected corrodents in furnace exposure tests, actually cause corrosion of SiC components.

Additional information:

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J. I. Federer et al., *Corrosion of SiC Ceramics in Synthetic Combustion Atmospheres Containing Halides,* ORNL-6258, Oak Ridge National Laboratory (December 1985).

NDE (Nondestructive Evaluation) of Adhesive Bonds

This report describes the results of a successful effort to demonstrate the feasibility of using leaky Lamb waves to detect and delineate flaws in the bond surface of metal/rubber laminates, even when adherents remain in intimate contact. It is shown that the leaky Lamb wave method can detect and image a poorly bonded surface when conventional pulse-echo method failed even to detect the flaw. A new technique was implemented for preparing partially bonded surfaces by varying the percentage of adhesive coverage, and results are provided that illustrate the sensitivity of the leaky Lamb wave method in detecting different surfaces prepared by this technique. An analytical model of the leaky Lamb wave phenomenon in homogenous, isotropic metal/rubber laminates is described. Numerical results for a metal/rubber laminate immersed in water are included.

Of particular interest to the Navy are adhesive bonds formed between rubber and metallic adherents. Rubbers and other elastomeric materials are used to protect and seal various components of hardware employed in or operated at sea, specifically, underwater transducers, connectors, etc. A reliable long-term bond between the elastomeric seal and the metallic structural member is essential for effective and efficient performance of the device. For example, the electroacoustic components of sonar transducers are protected from the seawater environment by a rubber or urethane seal that functions both as a water barrier and as an acoustic window. A seal that leaks in-service, as a consequence of a poor or improper bond, will degrade system and therefore mission performance. The rubber-to-metal bonding problem is thus a very important subset of the generic bonded joint problem. The specific focus of a project was rubber/metal laminates where the layers, though not bonded, remain in intimate contact. Conventional ultrasonic techniques have shown little-or-no success on this problem. The applicability of the LLW method to evaluation of bond quality, where bond quality is here defined as the degree of adhesive coverage, was also examined.

A long range goal of this work is to develop and engineer a nondestructive method for evaluating the bond state in the rubber annulus of a sonar transducer head mass assembly (HMA), for example, the TR-317( ), on a production-line basis. The work reported here employed metal/rubber structures dimensionally similar to the TR-317 ( ) HMA, with programmed flaws in the bond surface, or with a specifiable degree of adhesive coverage. The results demonstrate the feasibility of using leaky Lamb waves to detect and evaluate flaws in metal/rubber bond surfaces and the increased sensitivity of the LLW method over a conventional pulse-echo method. Flaws in bonded surfaces were reliably detected and delineated using LLW where a conventional pulse-echo method was unable even to detect the flaws.

On the basis of the work performed it is concluded that: the feasibility of using the LLW method to detect and delineate bond flaws in metal/rubber laminates when the adherents remain in intimate contact was successfully demonstrated; the improved sensitivity of the LLW method over conventional pulse-echo ultrasonic methods was dramatically shown; the LLW method is capable of providing a quantifiable measure of the bond state, e.g., the degree of adhesive coverage, of a bond surface variations in material properties, i.e., inhomogeneity, can deleteriously affect detection of a bond flaw or assessment of bond state, but there are straightforward procedural adjustments and/or signal processing measures which can reduce these effects.

FOR ADDITIONAL INFORMATION:

A full description of this activity is contained in a backup report which may be purchased from NTIS, Springfield, VA 22161; (703) 487-4650.

NTIS order number: AD-A184823/NAC
Price code: A04

NMR Images of Solids Produced

A team of scientists at the Naval Research Laboratory (NRL) reports the development of a new technique that has been used in the laboratory to obtain two-dimensional nuclear magnetic resonance (NMR) images of solid specimens, establishing a new method for looking inside solids without damaging materials.

The research team states that the NMR technique is important to the Navy and Department of Defense because, as organic matrix composites (such as graphite-reinforced epoxies) are introduced into Naval service, the demands for nondestructive evaluation of polymeric, anisotropic materials also increase. NMR imaging of these solids by the NRL technique could be one method to accomplish this nondestructively.

The NMR imaging has been limited primarily to liquid-like specimens, rather than solids, which are of interest to the Navy. The recent development in the medical field of magnetic resonance imaging is a prime example of imaging biological samples containing liquid water.

Scientists note that magnetic resonance imaging is based on the well-known observation that the nuclei of a sample inside a magnet will absorb and emit radio frequency signals precisely at a frequency (resonance condition) determined by the strength of the magnetic field. In imaging, the strength of the magnetic field is made to vary across the sample, and so the resonance frequencies will vary across the sample with the resulting spectrum of frequencies creating an image of the specimen.

However, imaging in a solid is very difficult because nuclei respond to the presence of other nearby nuclei through their mutual dipolar coupling. Unless special steps are taken, this strong dipolar coupling creates local random variations in the size of the magnetic field which can be three orders of magnitude larger than variations used for imaging, thus hopelessly blurring the NMR image.

The NRL scientists incorporated into the imaging a method which reduces the dipolar coupling by orders of magnitude, through a special sequence of intense radio frequency pulses applied to the sample. With this technique they produced a two-dimensional image from the hydrogen nuclei in a solid sample composed of an inner cylinder of the plastic crystal adamantane and outer of annulus neoprene rubber.

For Additional Information:

Backup material on this effort is available from:

Navy Domestic Technology Fact Sheet
Reader Reply Service
Code E211
Naval Surface Weapons Center
Dahlgren, VA 22448-5000
(703) 663-8921

Refer to 120704/TN

Process Developed for Making Superconductors

Scientists at the Naval Research Laboratory (NRL) have developed a process by which high-temperature superconductors can be rapidly deposited on almost any backing material of almost any shape. The method can be used to produce large quantities of superconductors cheaply and in technologically useful forms.

The recent discovery of high temperature (T_C) superconductivity in copper-oxide-based ceramics has spawned a flurry of materials research throughout the world. A joint research effort between NRL and the State University of New York at Stony Brook has led to a major breakthrough in the production of these materials. Specifically, a technique has been developed whereby high T_C superconductors can be rapidly deposited on almost any backing material of almost any shape.

Unlike normal materials, a superconductor is unique in that it exhibits no resistance to the passage of an electrical current. Consequently, electrical energy can be transported absolutely without loss. It is this property which will be exploited in this new process to make lossless power lines, electric motors, magnets, generators, and a host of other electrical devices. Prior to the discovery of these new ceramics, the principal limitation to large-scale application of superconductivity had been the extremely low temperatures required.

Until recently, the best known superconductor only operated at temperatures below -250° C, about 23 degrees above absolute zero. Earlier this year a new ceramic was discovered which became superconducting at about -180° C, significantly above the boiling temperature of liquid nitrogen. This made superconductivity a much more attractive technology.

One lacking component, however, was a method of mass fabrication of useful superconducting parts. These new materials are hard, brittle ceramics, containing several elemental metals that heretofore have been fabricated through a complex series of high-temperature laboratory processes.

For Additional Information:

Backup material on this effort is available from:

Navy Domestic Technology Fact Sheet
Reader Reply Service
Code E211
Naval Surface Weapons Center
Dahlgren, VA 22448-5000
(703) 663-8921

Refer to 121004/TN

NASA Tech Brief
National Aeronautics and
Space Administration

Advances in Thermoelectric Materials

Rare-earth chalcogenides and boron-rich borides show promise.

A report discusses the search for materials that will perform more efficiently in high-temperature thermoelectric conversion. It begins with a summary of developments during the past three decades. This is followed by a brief introduction to the theory of thermoelectric energy conversion, then by experimental findings and by some additional theory on specific materials.

The efficiency of conversion of heat to electrical energy in a thermoelectric couple increases with the difference between the squares of the Seebeck coefficients of the two materials and is reduced by heat conduction and Joule heating. These effects are summarized in a figure of merit, Z, which appears in the equation for the conversion efficiency and has the dimensions of the reciprocal of temperature. As Z increases, so does the efficiency. It is also common to use a modified definition of Z for a single material and then to compare different materials in terms of the dimensionless parameter ZT (where T = absolute temperature.)

Early theoretical work explained the transport properties of and guided the development of materials with high conversion efficiencies. In general, it has been found that the Seebeck coefficients of metals are too low, while the electrical resistivities of insulators are too high. Good compromises (the highest Z values) are made by choosing highly doped semiconductors that have intermediate Seebeck and resistivity values. The more significant developments have involved the estimation of optimum doping concentrations, the reduction of thermal conductivities by solid-solution doping, and the development of a variety of materials with $ZT \approx 1$ in the temperature range of 300 to 1,200 K.

It would be a breakthrough to find materials with $ZT \gg 1$, that can withstand large hot-junction temperatures. The search has led to two classes of candidate materials: (1) the rare-earth chalcogenides, which have high vacancy concentrations, behave as conventional, highly degenerate n-type semiconductors at room temperature, and become partially degenerate at higher temperatures; and (2) the boron-rich borides, which exhibit hopping p-type conduction. In the interest of the compatibility of materials, it would be desirable to fabricate a thermocouple from n- and p-legs of the same compound. However, it appears extremely difficult to dope rare-earth chalcogenides p-type or boron-rich borides n-type.

This work was done by Charles Wood of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "High Temperature Thermoelectric Energy Conversion," NPO-16885 /TN*

FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD 21240; (301) 621-0100 Ext. 241*

REFER TO THE NUMBER LISTED AT THE END OF THIS ARTICLE

NASA Tech Brief
National Aeronautics and
Space Administration

Ceramic Adhesive for High Temperatures

The fused-silica/magnesium-phosphate adhesive resists high temperatures and vibrations.

Lyndon B. Johnson Space Center, Houston, Texas

Developed to bond gap fillers to low-density ceramic insulating tiles used in the thermal-protection system of the Space Shuttle, a ceramic adhesive can be used in aerospace, metallurgical, ceramic, electronic, and other applications where conventional adhesives cannot meet requirements for service at high temperatures. The adhesive consists of a base material of fused silica and a bonding agent of magnesium phosphate.

An older procedure for filling unacceptably large gaps between the tiles involved room-temperature-vulcanizing silicone-rubber adhesives, which could not tolerate temperatures above 550 °F (288 °C) and therefore had to be replaced after each mission. The new adhesive, which has a coefficient of expansion compatible with that of the tiles, is unaffected by extreme temperatures and by vibrations. Assuring direct bonding of the gap fillers to the tile sidewalls, the new adhesive obviates the expensive and time-consuming task of the removal, treatment, and replacement of tiles.

The process for filling tile gaps is as follows:

- Water and colloidal silica are added to the ceramic adhesive powder, and the mixture is stirred to a homogenous paste.
- The surfaces of the shim and the tile to be joined are wetted thoroughly.
- The ceramic adhesive is applied to the surface of the shim.
- The shim is installed against the tile sidewall, which has been diamond-abraded, and pressure is applied to assure full contact.
- The adhesive is cured for 24 hours in air.

This work was done by Everett G. Stevens of Rockwell International Corp. for **Johnson Space Center.**
MSC-21085/TN

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NASA Tech Brief
National Aeronautics and
Space Administration

Degradation of Reflectors and Dielectrics

Terrestrial and orbital effects are described.

A report describes the important degrading effects of the atmosphere and outer-space environments on reflective surfaces and dielectrics. For reflective surfaces, the terrestrial effects include soiling on glass surfaces and their changes with time. The space effects include the ultraviolet enhancement of contamination and possible surface erosion due to solar radiation, the impact of debris, and interactions with atomic oxygen. Dielectrics are similarly affected in both environments.

It is known from solar-energy programs that the primary agents of the degradation of reflectors in terrestrial applications are natural aerosols from vegetation, dust, ozone, and such industrial pollutants as sulfur. The main degradation effects in terrestrial applications are caused by water vapor coupled with airborne dust. In certain geographical regions, surfaces are damaged by hail. In low orbits around the Earth, the degrading agents are space debris, contaminating volatile materials emitted by adjacent equipment, and atomic oxygen. Damage by micrometeorites and photolysis of surface contaminants by ultraviolet or particulate radiation is also important.

Insulators that perform well in terrestrial applications may perform poorly in satellite applications. On the Earth, factors that degrade insulators are the same as those that degrade reflective surfaces. However, for insulators the primary concern regards the buildup of contamination surface layers that provide electrical-discharge paths over the surfaces. It has been found that water vapor, coupled with dust and temperature cycles due to weather, causes the most damage. In desert areas, insulation does not require frequent washing except near industrial pollution sources. In coastal areas, the presence of humidity and contamination necessitates frequent washing.

The effects of the orbital environment upon insulators are more complex than originally thought. The response of an insulator to postulated radiation, atomic oxygen, and contamination needs to be known for success in an intended application. Orbital altitudes, radiation-resistant materials, and low-outgassing adjacent materials may have to be chosen with a view toward the minimization of degrading effects.

This work was done by Frank L. Bouquet, Edward F. Cuddihy, and Carl R. Maag, Jr., of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "Terrestrial and Space Effects on Reflective Surfaces and Dielectrics," NPO-16711 /TN*

FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD 21240; (301) 621-0100 Ext. 241*

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NASA Tech Brief
National Aeronautics and
Space Administration

Glass-Bead Blasting Alters Antenna Surface

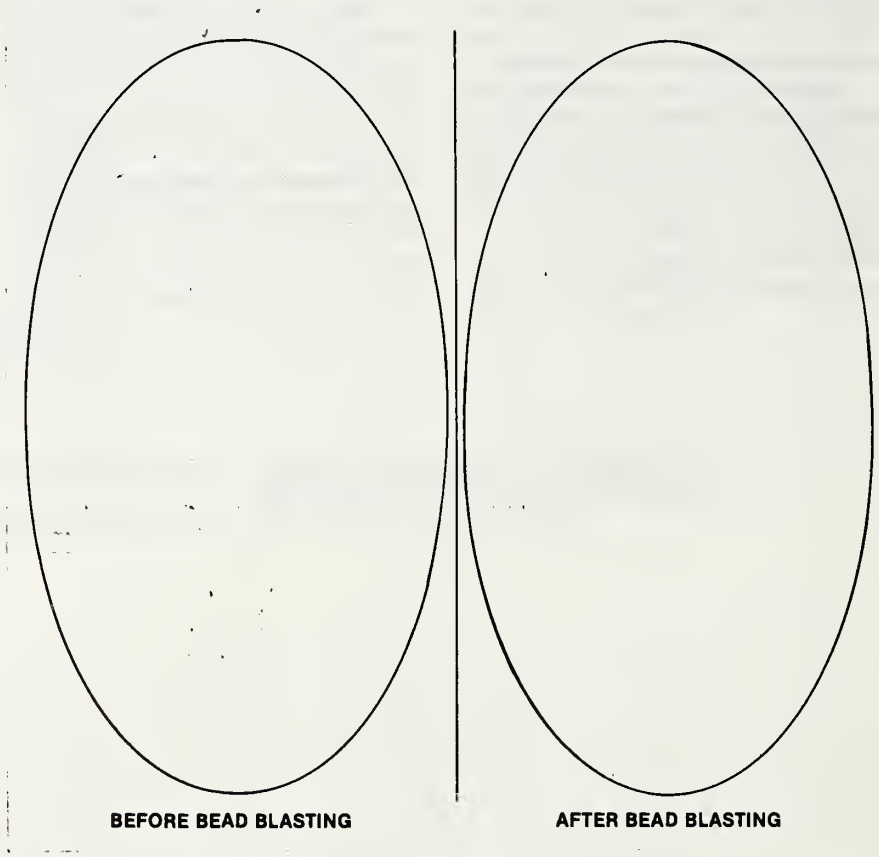
Thermal-emissivity properties are improved, and focal length is adjusted.

NASA's Jet Propulsion Laboratory, Pasadena, California

Experiments have shown that gentle blasting with glass beads can produce beneficial changes in the macroscopic surface shapes and in the microscopic surface features (textures or finishes) of lightweight microwave reflectors made of thin metal reflective surfaces on deformable substrates of aluminum honeycomb. Until now, it has been difficult to make microwave reflectors from metal honeycomb stock because fabrication techniques that adjust surface shapes to desired contours can also remove metal and cause unwanted changes in the thermal emissivity/absorptivity of the surfaces, while techniques that achieve the desired thermal-radiative properties can also change surface contours undesirably.

In a typical fabrication experiment, 50-μm glass beads were sprayed by hand at about 15 psi (100 kPa) on a concave reflector surface. This treatment did not remove metal or damage the surface but did change the surface finish and appearance to flat gray. The altered surface finish satisfied the thermal-radiative specification. The bead blasting also changed the surface contour (see figure), increasing the focal length by about 0.080 in. (2 mm).

This work was done by James W. Fortenberry, Richard L. Jilka, Boyce Kimmel, Ramon D. Garcia, Richard E. Cofield, Gerhardt J. Klose, and Thomas O'Toole of Caltech for **NASA's Jet Propulsion Laboratory**.
NPO-16898/TN



Surface-Contour Maps show the shape of an aluminum-honeycomb reflector before and after blasting with glass beads.

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NASA Tech Brief
National Aeronautics and Space Administration
Langley Research Center, Hampton, Virginia

Licensing Opportunity

Polyphenylquinoxalines Containing Alkylenedioxy Groups

Better processability is achieved through the lowering of glass-transition and melt temperatures.

New polyphenylquinoxalines (PPQ's) have been prepared from the reaction of novel bis(alpha-diketones) with aromatic bis(o-diamines). These PPQ's contain alkylenedioxy groups in their repeating units. They have lower glass-transition temperatures and melt viscosities and, consequently, better processability than the all-aromatic PPQ's. The tensile strength, modulus, elongation, adhesive strength, fracture energy, and solvent resistance of the new polymers are comparable with the properties of known PPQ's.

The incorporation of a flexibilizing segment such as an aliphatic or an alkylenedioxy group into the repeating unit of an aromatic/heterocyclic polymer is an effective way of reducing the glass-transition temperature and improving the processability. In this case, the flexibilizing alkylenedioxy unit was incorporated into the bis(alpha-diketone) portion of the PPQ repeating unit.

The PPQ's containing alkylenedioxy units of two to six carbon atoms within the backbone were prepared in high-molecular-weight forms. Their glass-transition temperatures ranged from 203 to 241 °C, decreasing with the increasing lengths of the alkylenedioxy groups. Solution-cast films had tensile strengths, tensile moduli, and elongations at room temperature as high as 14,400 psi (99 MPa), 378,000 psi (2.61 GPa), and 8.1 percent, respectively. The PPQ's were readily compression-molded to provide compact tension specimens that had fracture energies as high as 10.5 in.-lb/in.^{2} (1.84 kJ/m^2). Titanium-to-titanium tensile shear specimens provided average strengths of 4,400 psi (30 MPa) at 26 °C, 3,100 psi (21 MPa) at 177 °C, and 2,010 psi (13.9 MPa) at 203 °C. The PPQ's were resistant to normal aircraft fluids but were soluble in chlorinated solvents. These polymers are potentially useful as adhesives, coatings, films, and molded products, particularly for aerospace applications.

This work was done by Paul M. Hergenrother of **Langley Research Center**, *Stephen J. Havens of PRC Kentron, Inc., and Frank W. Harris of the University of Akron.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Langley Research Center Refer to LAR-13601 /TN

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NASA Tech Brief
National Aeronautics and Space Administration
Goddard Space Flight Center, Greenbelt, Maryland

Licensing Opportunity

Thermosetting Fluoropolymer Foams

Uses include coatings, electrical insulation, and structural parts.

A new process makes fluoropolymer foams with controllable amounts of inert-gas fillings in the foam cells. Unlike foamed thermoplastic fluoropolymers, the thermosetting fluoropolymers do not require foaming additives that leave undesirable residues and do not have to be molded and sintered at temperatures of about 240 to 400 °C. Consequently, the thermosetting polymers may be better for use with electronic or other parts that are sensitive to high temperatures or residues.

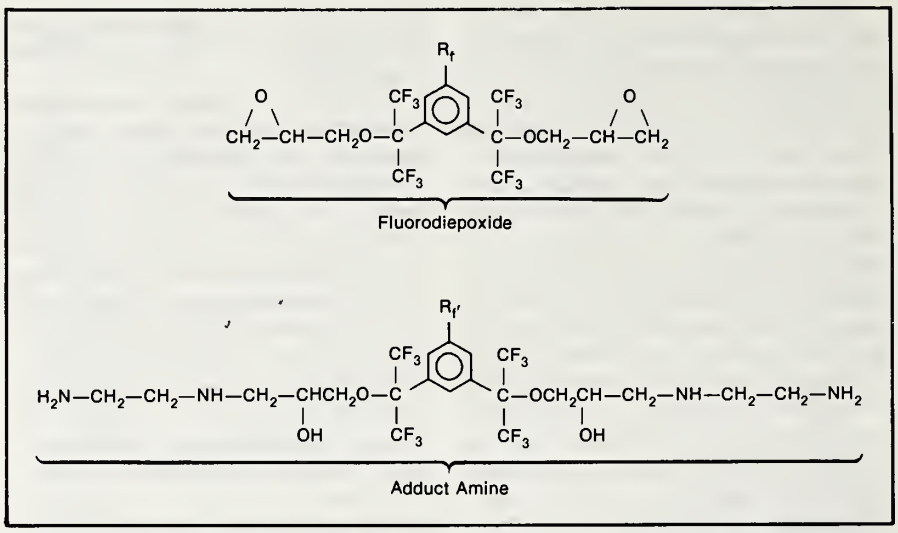
A typical thermosetting polymer is made from a fluorodiepoxide and a curing agent that is usually an adduct amine (see figure). These ingredients are liquid at or near room temperature. First, they are mixed in stoichiometric or other suitable amounts. After deaeration in a vacuum, the mixture is placed in a chamber, which is then pressurized with the desired filling gas at a pressure of several atmospheres.

The filling gas can be air, oxygen, nitrogen, or any of a variety of elements and compounds that do not react chemically with the mixture. Experiments have shown that the gas reacts physically with the mixture in a controlled way and that the gas can be squeezed into the mixture as long as the fluorine content of the mixture is at least 30 to 40 percent by weight.

The mixture is allowed to cure partially at room temperature. Once the mixture has gelled, the gas is trapped in the polymer.

The partially cured polymer is removed from the pressure chamber and heated to complete the cure. While the polymer is being cured, the trapped gas causes it to foam by heating. The depth of foaming depends on the type of gas and can be increased by increasing the pressure during the gas-trapping/partial-curing stage.

The type and amount of gas can be selected to impart a desired mass density. For example, the material might be foamed to the maximum possible extent to reduce the cost. (Fluoropolymers are relatively expensive.) A gas filling — possibly sulfur hexafluoride — might be chosen to enhance the dielectric properties of a foam to be used as electrical insulation. Another gas [oxygen or Freon (or equivalent)] might be chosen to support or retard combustion or to perform other specific functions.



These Ingredients are mixed at or near room temperature to form a thermosetting fluoropolymer. The fluorine content varies with the sizes of the perfluoroalkyl groups, R_f and R_f'.

This work was done by Sheng Yen Lee of **Goddard Space Flight Center.**

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Goddard Space Flight Center
Refer to GSC-13008./TN

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REFER TO THE NUMBER LISTED AT THE END OF THIS ARTICLE

ICAN: Integrated Composites Analyzer

This program calculates macromechanical, micromechanical, and related environmental effects.

The importance of, and need for, multilevel analysis in the design of structural components made of multilayered fiber composites is well documented. As a result, the computer code ICAN has been developed to carry out comprehensive linear analyses of multilayered fiber composites. The program contains the essential features required to design structural components made from fiber composites. The program is an outgrowth of two in-house computer codes: MFCA (multilayered filamentary composite analysis) and INHYD (intraply hybrid composite design).

MFCA provides (1) micromechanical theories for the thermoelastic properties and the stress-level limit of a single ply or as functions of the properties of constituent materials and the particular fabrication process, (2) the combined stress/strength criterion for a single ply, and (3) analysis of the response of a single ply or of an entire multilayered composite structure, where the effects of interply layers are taken into account.

INHYD is the result of recent theoretical and experimental investigations of the mechanical behavior of intraply hybrids. The theoretical methods and equations, together with those for hygrothermal effects, have been integrated to form this computer code, which predicts hygral, thermal, and mechanical properties of intraply hybrid composites.

The synergy of MFCA and INHYD, together with several significant enhancements, has produced ICAN, which utilizes the micromechanical design of INHYD and the laminate analysis of MFCA to build a capability for comprehensive analyses of structural composites. One enhancement is a data base of material properties for commonly used fibers and matrices. The program searches and selects the appropriate properties from its library.

The inputs to the code are the properties of the constituent materials, factors that reflect the fabrication process, and the size and shape of the composite structure. The code performs micromechanics, macromechanics, and analysis of laminates, including the hygrothermal responses of fiber composites. The code outputs are the properties of the various plies and composites, the responses of composite structures, and results of analyses of stresses in composite structures, including detailed information about failures.

The code is in FORTRAN IV and can be used efficiently as a package in complex structural analysis programs. In addition, ICAN has been tested on the UNIVAC 1108, IBM 370, and CRAY 1 operating computer systems.

This program was written by Christos C. Chamis of **Lewis Research Center** *and Pappu L. N. Murthy of the National Research Council.* *LEW-14468 /TN*

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Laminate-Moisture-Analysis Computer Program

The diffusion and the deleterious effects of moisture can be predicted.

The General One-Dimensional, One Material Moisture Analysis computer program was developed to predict the moisture gradient across a composite laminate where moisture enters two surfaces and flows in the direction between these surfaces. The mechanical properties of composites, especially matrix/fiber combinations, are adversely affected by moisture when subjected to high temperatures. This program was designed to monitor the flow of moisture in the Space Shuttle Orbiter payload bay doors but is applicable for general use.

Advanced composite structures are usually degraded by absorbed moisture. The resin in a composite part absorbs water, which slowly diffuses across the material. If the material is not chemically changed by this absorption, the detrimental effect on such properties as shear, plate buckling, and ply delamination can be reversed. At high temperatures, the resin may change from a glassy to rubbery state, and the thermal properties are altered drastically.

This program solves Fick's law of diffusion with the user's choice of finite-difference solution: Crank-Nicholson or backward-difference method. Diffusivity is allowed to be a function of moisture concentration and temperature, and the external surfaces can be exposed to transient-relative-humidity environments.

The input to the program consists of such laminate parameters as diffusivity, glass-transition temperature, and solubility and of such environmental factors as the initial humidity and the temperature history. Typical results include temperature and moisture levels at node points and the average moisture content of the laminate. The program produces plots of the moisture content against time, the temperature against time, and the margin of safety against time.

This program is written in FORTRAN IV (IBM Level H extended) for batch execution and has been implemented on an IBM 360 computer operating under OS/MVS with a central-memory requirement of approximately 152K of 8-bit bytes. This program was developed in 1982.

This program was written by Ronald T. Martin of Rockwell International Corp. for **Johnson Space Center**. *MSC-21143 /TN*

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Analytical Instruments and Components

01-05-0188

Slow Neutron Reflectometer (POSY II)

New application of neutron reflection techniques measures interdiffusion of polymers

The pervasive use of polymers in everyday life and in a constantly increasing number of technological innovations requires research that is aimed at the preparation of specific materials as well as the characterization of their chemical and physical properties. Relevant questions in this context are:

- How can two polymers be bonded to each other?
- How does a polymer attach itself to a surface--or, better, which part of a polymer prefers to stick to the surface?
- How does a melt of two polymers wet the surface?

Polymers scientists have discovered that they can answer these questions by making use of a unique instrument at the Intense Pulsed Neutron Source (IPNS) at Argonne National Laboratory.

The instrument is a slow neutron reflectometer. The first prototype in the world (the polarized neutron reflectometer--POSY) was constructed at Argonne primarily for studies of magnetism, which were carried out with a polarized neutron option. The technique involves a beam of neutrons that are partially reflected at the surface and near-surface interfaces of materials, very much like a beam of light. However, the amount of reflection from each layer boundary depends on the composition of the boundary, either its magnetic properties or its atomic constituents (e.g., the presence of hydrogen or deuterium). By continuously changing the energy of the neutrons, the composition of various depths is determined and the depth profile is then reconstructed by looking at the reflection for all energies. By this method, the instrument determines the chemical or magnetic profile perpendicular to the surface of the sample. For instance, if the sample is made of two layers of different polymers, the amount of interdiffusion can be determined, with the remarkable resolution of 2-3 nanometers--at least an order of magnitude better than the next-best technique used to date (Forward Recoil Spectrometry).

The instrument was first used in September 1987 for preliminary measurements of polymer interfaces in collaboration with scientists from IBM. The power of the technique was immediately recognized and, due to the heavy use of POSY, it was decided that a new instrument should be constructed that is dedicated to polymer research using pulsed neutron reflection. To this end, a contribution from IBM of $150,000 was received in December 1987, and the new instrument, to be known as POSY II, is under construction while experiments are continuing on the present instrument.

Even prior to the polymer applications, the unique and innovative aspects of POSY were recognized by a DMS/BES Award for Outstanding Scientific Accomplishment in 1986 and an IR•100 Award in 1987.

Additional Information

Key Words: user facility, neutron reflection, polymer, interdiffusion, magnetic profile, chemical profile

Patent Status: Not patented.

Potential Applications/Spinoffs: polymer bonding and interdiffusion

Literature: G. P. Felcher et al., Review of Scientific Instruments, 58(4), April 1987.

For More Information: Contact the Technology Transfer Center, 9700 S. Cass Ave., Argonne, IL 60439 (312/972-7694).

Medicine & Biology

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437 IMAGESystem — Improved imaging and data handling for gel electrophoresis.

The Muscular Biomechanics of Human Posture

PROBLEM: Persons with paraplegia need to regain functional use of their legs. An essential prerequisite for this is the restoration of upright posture, as the maintenance of posture is fundamental to movement. The human body is naturally unstable in the standing position, and upright posture is sustained with the fine coordination of many muscles. An understanding of the biomechanics and muscular coordination of posture is requisite to designing Functional Electrical Stimulation (FES) systems for paraplegics.

SIGNIFICANCE: FES is potentially a useful method for restoring upright posture in paraplegics. For FES to be used effectively, we must know which muscles to stimulate, and how they should be coordinated.

BACKGROUND: Experimental research on posture suggests that muscular coordination is simplified by the organization of muscles into groups, with muscles in each group working together as a muscular synergy. The experimental identification of synergies is limited, however, since experiments are unable to discriminate between the activities of nearby muscles, and are unable to monitor the function of deep muscles.

HYPOTHESIS: An engineering model can give much insight into the muscular biomechanics of upright posture. It is hypothesized that the muscles used in synergies are consistent with those used to maximally accelerate the body from a disturbed position towards the upright standing position.

APPROACH: An engineering model, based on the properties of the musculoskeletal system, has been developed (see Fig 1). The body is represented as four rigid segments: foot, shank, thigh, and torso. The musculoskeletal system is modeled in detail, and 14 muscles of the ankle, knee, and hip are included (see Section 6.2.1.2). The muscles are represented by a generic dimensionless musculotendon model, and this is scaled to each muscle/tendon by the muscle strength, muscle fiber length, and tendon slack length. The model considers body positions from forwards and backwards swaying, with the knees fully extended and the feet flat on the ground. Optimization techniques are used to identify the functional significance of different muscles, their organization into synergies, and the body positions in which each synergy is effective. Additionally, optimization is used to determine quantitatively the significance of the various physical constraints, such as keeping the feet on the ground and keeping the knees fully extended.

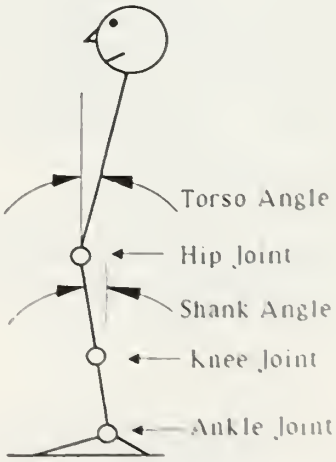

Fig. 1. Skeletal model.

STATUS: The computer model has been developed and thoroughly tested. Preliminary results predict muscular synergies which are consistent with experimental work. Because muscles can only pull, and not push, the different muscular synergies are effective in only certain body positions.

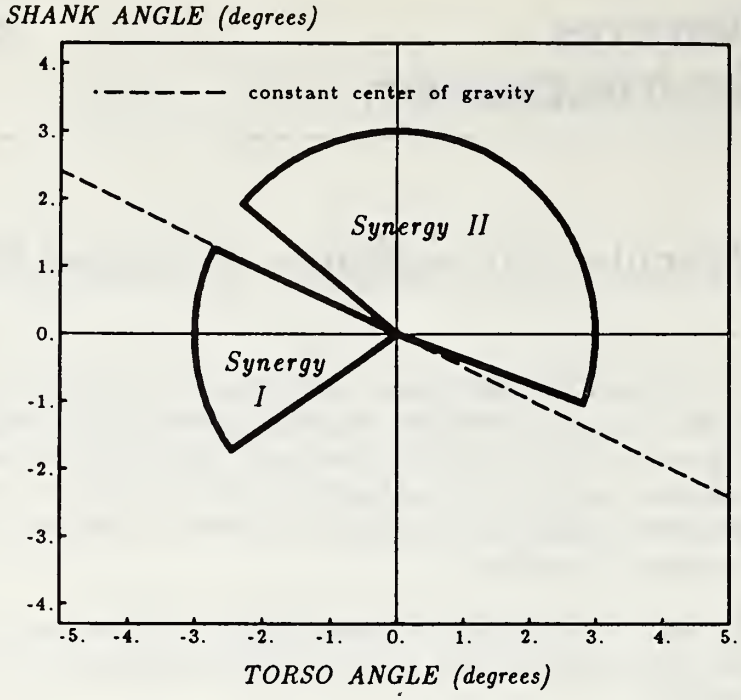

Fig. 2. Plot of lower-limb muscle synergies.

Fig. 2 plots the deviation of the shank segment from the vertical versus the deviation of the torso segment from the vertical. (The sign convention is positive for positions of forward swaying.) The pie chart shows two synergies: synergy I using muscles on the front side of the body, and synergy II using muscles on the back side of the body. As can be seen from the figure, the use of either synergy I or synergy II is restricted to a portion of the body positions. The results identify the separate contribution of muscles such as soleus which have been neglected or grouped with other muscles in previous work. Also, the optimization results provide insight into the specific way in which posture is recovered. For example, should the upper body recover first, or should the leg? In general, it appears that the physical constraints severely restrict direct acceleration towards the upright position. Insufficient muscle strength does not seem to be a primary problem; the major difficulties are keeping the feet flat on the ground, due to the short length of the feet, and keeping the knees in the fully extended position. Presently we are relaxing these constraints to investigate their effects on muscular synergies and the ability to accelerate towards the upright position. Additionally, this work is being prepared for publication.

PUBLICATIONS:

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For Additional Information:

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NIH Research & Technology

U.S. Department of Health and Human Services Public Health Service National Institutes of Health

Antigen Delivered by Biodegradable Polymers may Provide Long-Lasting Immunity

Vaccine-containing implanted polymer devices that biodegrade into substances able to further strengthen the body's immune response may someday provide an alternative to traditional vaccination under special circumstances. Such polymer systems may eventually have other medical applications as well, such as for controlled release of high-molecular-weight substances like interferon and insulin.

Dr. Robert Langer of the department of applied biological sciences at the Massachusetts Institute of Technology (MIT) in Cambridge and the department of surgery at Children's Hospital in Boston says the biodegradable polymer systems are not intended to replace standard vaccinations. "These kinds of approaches might be useful if you want to reduce the number of shots somebody has to get, or if you need to get higher antibody titers," Dr. Langer says. As examples, he cited the desirability of using a single dose of vaccine to protect people in Third World countries against diseases like hepatitis and of inducing high antibody titers when immunizing people against AIDS.

To avoid the inconvenience and stress of surgically implanting a controlled-release polymer system, in some cases the device might be made tiny enough to be injected. Dr. Langer reports that polymer microspheres only a couple of hundred microns in size have already been made. "You could inject them through a large needle, and as we develop better microspheres, probably even through a small needle," he explains.

Obtaining controlled release of high-molecular-weight substances from polymer systems has been a major challenge, he says. Over the past several years, Dr. Langer and his colleagues have successfully developed different polymers from which it is possible to slowly release antigens of various molecular weights and get a favorable antibody response.

Developing polymers for controlled release of even more complex substances like killed viruses will be among the future challenges, he says. The poly-

The recent antigen-containing biodegradable polymer developed by the MIT researchers exerts two adjuvant-type effects. First, like all the polymers they have developed and tested for the controlled release of drugs, including those that do not degrade while in the body, the implant serves as a depot from which vaccine is slowly released. Hopefully the constant stimulation of the immune system may either totally eliminate or greatly reduce the number of later booster doses required to maintain sufficient antibody levels, Dr. Langer notes. Secondly, the device biodegrades into an amino acid that exists naturally in the body and possesses powerful adjuvant qualities.

In the future, Dr. Langer hopes to extend the concept of pulsed release to even more complex and "smart" polymer systems involving the action of enzymes: for example, he explains, a polymer system for the slow release of insulin might also contain a specific enzyme. In the presence of increased glucose, the enzyme would change the microenvironment of the polymer so that more insulin would be released. Dr. Langer and his MIT colleagues have already achieved the near-constant release of insulin from the nonbiodegradable EVAc polymer in diabetic rats, with resultant decreases in blood glucose levels for over 100 days as well as improvement in other clinical symptoms. In addition, Drs. Langer, Herman Eisen, and Margaret Wheatley have been developing a microencapsulated liposome that also can provide pulsatile release.

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Photo courtesy of Dr. Robert Langer

This cross-section of a biodegradable polymer used in immunization studies shows the many interconnecting pores created when antigen particles are added to the matrix. The larger the size and number of antigen particles, the larger the pores and the faster the vaccine diffuses when the polymers are implanted under the skin. For vaccination, it may be desirable to slow the release of antigen and thereby prolong immunologic stimulation.

Funding for the work discussed in this article was provided in part by the Animal Resources Program of the National Institutes of Health Division of Research Resources, the National Institute of General Medical Sciences, Johnson & Johnson, the American Diabetes Association, the Juvenile Diabetes Foundation, the Eli Lilly Corporation, NOVA Pharmaceuticals, the Monsanto Company, and the ALZA Corporation.

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Refer to item XI, No. 12/TN

NIH Research & Technology

U.S. Department of Health and Human Services Public Health Service National Institutes of Health

Copper and Penicillamine Cluster Ion has Potential Applications in Both Diagnostic Imaging and Therapy

A mixed-valence cluster ion of copper and penicillamine, in both radiolabeled and unlabeled forms, has potential applications in both diagnostic imaging and therapy.

The cluster ion—$(Cu(I)_8 (Cu(II)_6 Pen_{12} Cl^{[illegible]}$—"has essentially no toxicity and is easily eliminated through the kidneys," says Dr. John R. Wright, of the department of physical sciences at Southeastern Oklahoma State University in Durant, Oklahoma, who played an active role in the development of the ion.

"The radiolabeled form has potential as an imaging tool, especially in kidney function studies," says Dr. Wright, noting that the cluster can almost certainly be used as a positron tomographic probe in studies of renal dynamics. Furthermore, the cluster ion in its radiolabeled form using the ^{64}Cu isotope might possibly be cross-linked to immunoglobulins and subsequently used in immunoassays or to target diagnostic or lethal amounts of the short-lived isotope to diseased tissues such as tumors, he suggests.

Dr. Wright and his associates became interested in copper cluster ions as biomedical probes and labels following earlier investigations into the physiological properties of the clusters. The cluster structure is produced when penicillamine reacts with cupric ion in the presence of chloride ion.

"We were wondering if this substance might be involved as an excretion product when D-penicillamine is used in chelation therapy to remove toxic excesses of copper, as in Wilson's disease (a copper-storage disease). Apparently it is not a major product, but the ion's physiological properties proved to be interesting," Dr. Wright says.

The penicillamine cluster was not toxic in mice or rabbits at doses at which cupric sulfate or cupric chloride would have been lethal. "This result doesn't seem surprising in view of the structure, in which the copper is fairly enclosed and inert," he notes.

Dr. Wright and his associates have demonstrated in animal studies that administering the unlabeled form of the cluster prior to administering the radioactive form greatly reduces the accumulation of the radioactive label in the liver and kidneys.

To assess the interactions between the cluster ion and tissues in an intact organism, the investigators obtained in vivo measurements of the distribution of the ^{64}Cu-labeled cluster among various tissues and organs of mice at a dose of 0.1 mg/kg. Mice were given the dose of radiolabeled cluster intravenously and 20 minutes later the distribution was analyzed by spectrometry. The radiolabel accumulated in the kidney and liver but, as expected, was highest in the urine because of the cluster's rapid renal clearance.

These studies were then repeated but the unlabeled cluster was injected 5 minutes before injecting the labeled form. Twenty minutes after the labeled form had been injected, the accumulation in the liver was significantly lower than in the previous experiment but the amount accumulated in the kidney did not change significantly. In both experiments, little radiocopper was found in other tissues.

The labeled and unlabeled forms of the cluster ion compete for binding sites in the liver. These results indicate that undesirable cluster interactions might be avoided by first injecting unlabeled cluster, Dr. Wright says. The ability of the cluster ion to bind to the liver could be useful in tomographic imaging, he suggests.

The researchers have also studied whether the cluster is broken down in the liver. Collagenase-dispersed liver cell preparations were made from mice that had received intravenous doses of the cluster, but there was no evidence of the cluster ion in any of these preparations.

Injected intravenously, the cluster is cleared from the kidneys as inulin is. It could be used to measure renal clearance based on copper atomic absorption spectra. A small amount of the cluster could be injected intravenously, after which serum samples could be withdrawn at intervals and then quantified by copper atomic absorption.

When a baseline of endogenous copper determined from a serum sample prior to the cluster injection is subtracted from these measurements, a renal clearance value can be obtained from the copper-loss kinetics.

"All of this might be done in about 20 minutes," Dr. Wright says.

The copper-64 labeled cluster might be a useful probe for imaging renal dynamics. This isotope is a positron emitter with a half-life of 12.8 hours. The radiolabeled cluster is easy to prepare, and the synthesis and purification can be accomplished in 30 minutes.

Using very small intravenous doses, we found that part of the cluster accumulates in liver tissue, and it might have a positron tomographic application because of that," Dr. Wright says. At higher doses, nearly all of the radiolabel is excreted.

The cluster ion is a fairly inert vehicle. "If you transport a radioactive metal on it, the metal will

isotope exchange with counterion copper is slow. The ion is also fairly stable up to temperatures of 170 degrees Fahrenheit, he reports.

In addition, polymerized versions of the cluster have some potential for colorimetric assays. In his original work on the effect of penicillamine in Wilson's disease, Dr. Wright found an intense red-violet color when cupric and chloride ions were complexed with penicillamine, instead of the blue color characteristic of the cupric ion.

Dr. Wright and his associates are currently identifying ways to cross-link the cluster to antibodies so it could carry the radiolabel immunospecifically. They have found that when a cross-linking agent is used, the penicillamine cluster can be linked to bovine or human albumin, opening up new avenues for biomedical studies. The resulting product, which appears to be nontoxic in the unlabeled form, is easy to prepare and possesses reactive amine functional groups, making it appropriate for conventional antibody cross-linking strategies.

"We think these inorganic radiolabels might have some advantages, including stability and as a means for carrying short-lived isotopes," he says. "We are looking for ways to prepare very stable, cross-linkable forms of bismuth. The short-lived isotope bismuth-212 is especially suitable for tumor destruction in antibody-linked forms."

The penicillamine-copper cluster is only one of many such structural analogues, he notes. Penicillamine may be replaced by dimethyl cystemine or a mixture of compounds, and silver or nickel could conceivably be substituted for copper.

—*Barbara P. Hyde*

Courtesy of Dr. Wright

Dr. John Wright, of Southeastern Oklahoma State University, in Durant, uses the multinuclear magnetic resonance facility funded through a supplemental award for shared instruments from the NIH Division of Research Resources' Minority Biomedical Research Support Program to record the carbon-13 spectrum of a compound.

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The research described in this article was supported by the Minority Biomedical Research Support Program of the NIH Division of Research Resources.

NIH
Research & Technology

U.S. Department of Health and Human Services Public Health Service National Institutes of Health

Image Combining Microscope Resource

New and advanced imaging techniques for use in both light and electron microscopy are available at the University of Maryland School of Medicine at Baltimore. The techniques at the Image Combining Computer Microscope Facility are particularly applicable to studies in neurobiology.

The Biomedical Research Technology Program of the NIH Division of Research Resources is supporting the microscopy resource.

According to Dr. Edmund M. Glaser, the bioimaging resource provides a unique combination of sophisticated equipment and facilities to support highly specialized research projects. Collaborating researchers are encouraged to conduct light microscopy studies at the resource, where staff personnel are available to train them in operation of the system and in the analysis. The visiting researchers have the option, however, of gathering data at the resource and then having these data processed at their own institutions. Electron microscopy studies must be conducted off site because the resource does not yet have that capability, but the resource does have the capability of analyzing serial section electron micrographs.

Much of the work at the resource is aimed at the quantitative measurement and production of three dimensional images of cell structures, especially those of neurons and their components—axons, dendrites, and cell bodies.

According to Dr. Glaser, the facility is capable of supporting detailed examination of neuronal morphology as it relates to such areas as growth, learning, and aging, as well as the body's response to disease, drugs, and toxins. The techniques and systems available at the resource amplify the capability of scientists, allowing better analyses in morphology and pathology, which involve especially complex images.

The resource, Dr. Glaser says, strives to present complex structures in a relatively simple way so as to provide quantitative information. Computer processing of thick (350 micron) and serial sections result in stick figure images that represent the spatial orientation of the microscopic objects, allowing scientists to measure the length, thickness, and location of neural components in, for example, the cortex of the brain.

Most of the serial reconstructions are produced from slides prepared for light microscopy. These studies involve two aspects—visual and video. Dr. Glaser distinguishes visual from video in terms of what the eye and video camera can provide to the analysis. The human eye, he says, is unequalled in defining and identifying qualitative features and complex structures. The video camera allows quantitative analysis, for example the measurement of areas and thickness of cell components. Video also allows scientists to describe the cell in terms of image brightness or contrast. These gray levels allow the differentiation of cells and structures within cells.

This capability, a combination of visual and video analyses, streamlines many otherwise burdensome tasks involved in the three-dimensional reconstruction of cells. Researchers can edit graphic images while they are being acquired. Images can be digitized and stored in computer memory, allowing easy access to the images and simplifying the alignment of serial sections.

Core research is now being directed at developing image acquisition methods and procedures that further integrate the visual and video data acquisition techniques. By combining visual and video methods of analyzing images, the best attributes of both approaches can be applied, Dr. Glaser says.

Techniques now available at the resource are mostly used in analyzing and reconstructing images obtained using light microscopy. They can also be applied to electron and fluorescence microscopy.

Fluorescence microscopy promises to provide information about cells that might otherwise be invisible, Dr. Glaser notes. Using a SIT (silicon intensified target) camera, resource scientists are now planning to enhance images produced at light levels below those visible to the human eye. Clear or "noise free" images are then reproduced on a video monitor for study. Only a prototype of the fluorescence microscopy system currently exists. A fully operational system, Dr. Glaser says, should be available within a year.

At present the representation of cellular structure is controlled completely by the scientist with the computer helping to position the microscope stage. Dr. Glaser explains that at the usual magnification—up to about 1,000 power with the light microscope at the resource—the cell and its components cannot fit entirely in the field of view. Computer graphics, superimposed on the optical image of the object during the examination, allow scientists at the facility to trace contours of the tissue laterally and throughout the depths of the thick tissue section. Tracings are generated with a digital tablet.

This tablet is similar to a very sophisticated "mouse," a popular adjunct to the personal computer (PC) that is used to guide a cursor on the PC screen. Similarly, the digital tablet guides the cursor on the computer graphics screen that displays the contours

of cellular structures. Movement of the tablet also directs the computer on how to move the microscope stage.

Core research aimed at developing automated methods for tracing cell structures is going on in collaboration with the University of Maryland's Computer Vision Laboratory in College Park. These studies promise to open up new avenues for analyzing electron micrographs.

These systems will perform certain types of especially difficult three-dimensional tissue examinations, such as tracing multibranched dendrites and axons.

Ultimately the video image will be processed by the computer according to rules that approximate the way the human eye and brain interact in the analysis of images. Such expert systems, based on human experience and judgment, are still years away, according to Dr. Glaser.

Other research is directed at exploiting mini- and personal computers to perform laboratory image processing. Data storage is of particular concern. Dr. Glaser notes that it is important to use available memory as efficiently as possible in order to get maximum performance out of an imaging processing system. One solution is image data compression.

Because the images used in neurobiology are often redundant, Dr. Glaser believes they can be compressed into much smaller files without the loss of important data. This compression would permit not only the storage of more images, but because the images are stored in a smaller space, permit more rapid access to the images, greatly facilitating real-time imaging.

Most recently the resource scientists developed a version of the image combining microscope system that can run on a personal computer. In collaboration with an international corporation, Dr. Glaser and his staff have produced a system that has many of the capabilities of the larger one at the resource.

For more information about the PC system or the resource, contact:
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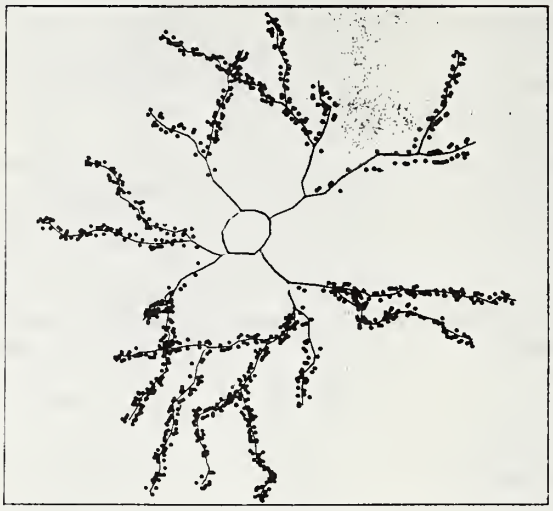
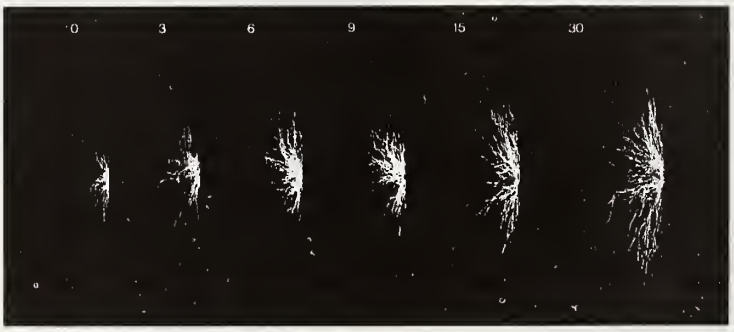
Graphics courtesy of Dr. Edmund Glaser



Dendritic spines appear as dots along the basal dendrites of the digitized image produced at the image combining microscope facility at the University of Maryland School of Medicine in Baltimore. Quantitative study of the cells has allowed researchers to determine that the onset of acoustical activity along the auditory pathway stimulates the development of dendrites.



A computerized projection of the normal development of auditory neurons in a rabbit from birth (day 0) to when the cells are mature (day 30). Knowledge of the branching structure allowed scientists at the image combining computer microscope facility at the University of Maryland in Baltimore to determine that the explosive dendritic growth at the onset of hearing occurs preferentially in the direction of the brain surface.

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United States
Environmental Protection
Agency

Atmospheric Sciences
Research Laboratory
Research Triangle Park NC 27711

Research and Development

EPA

Project Summary

Contributions of the Fluid Modeling Facility to EPA's Complex Terrain Model Development Program

The contributions of the EPA Fluid Modeling Facility (FMF) to the Complex Terrain Model Development Program (CTMDP) are described. These contributions included a wide range of laboratory studies and a limited amount of numerical modeling of flow and diffusion in neutral and stably stratified conditions in complex terrain. The goal of the CTMDP is the development of a dispersion model valid in complex terrain, with emphasis on plume impaction on nearby hills during nighttime stable conditions. Work at the FMF prior to the inception of the program divided the basic framework for the model—the dividing-streamline concept—and the focal point around which the field program was designed. Throughout the course of the CTMDP, the FMF interacted vigorously with the model developers by providing support in various ways. Early work provided direct support as an aid to planning the details and strategies of the field experiments and testing the limits of applicability of the dividing-streamline concept. Later work included exercises of ''filling in the gaps'' in the field data, furthering the understanding of the physical mechanisms important to plume impaction in complex terrain and in stably stratified flows in general, testing various modeling assumptions, providing data for ''calibration'' of various modeling parameters, and testing the ability of the laboratory models to simulate full-scale conditions. Simultaneously, the FMF responded to the needs of the regulatory arm of EPA, the Office of Air Quality Planning and Standards (OAQPS), by providing guidance concerning expected terrain effects and by conducting demonstration studies. Finally, several supplemental studies were conducted, broadening and expanding upon the specific requests of the model developers and the OAQPS.

Introduction

In the late 1970's the Office of Air Quality Planning and Standards (OAQPS) of the Environmental Protection Agency (EPA) identified a crucial need to develop an improved mathematical model that dealt with plume impaction from large sources located in mountainous terrain under stable flow conditions. A workshop was convened in 1979 to focus on complex terrain modeling problems and to develop recommendations to EPA with respect to the design of a program of experiments and model development efforts. Subsequently, the EPA outlined a plan to achieve the objective through an integrated program of model development, fluid modeling experiments and field studies of plume-terrain interactions on hills of progressively increasing size and complexity. This multi-year, multi-faceted program is known as the Complex Terrain Model Development Program (CTMDP).

The Fluid Modeling Facility (FMF) interacted vigorously with various groups participating in the CTMDP, and provided direct support and guidance in many different ways. The FMF research program has ranged from the development of broad guidelines and physical concepts to specific site studies and regulatory applications. The FMF has provided laboratory data to "fill in the gaps" in the field data and tested the validity of convenient modeling assumptions.

The complete report summarizes the contributions, both direct and indirect, of the FMF to the CTMDP. The discussion provides a historical perspective and a comprehensive list of FMF's accomplishments with respect to furthering the physical understanding of flow and diffusion in complex terrain. Over 65 publications have been generated from work conducted within the FMF on complex-terrain research. Only a few of the most important publications are highlighted herein.

Summary

The EPA Fluid Modeling Facility has conducted a wide range of laboratory studies and a limited amount of numerical modeling of flow and diffusion in association with the CTMDP. The goal of the CTMDP is the development of a dispersion model valid in complex terrain, with emphasis on plume impaction on nearby hills during nighttime stable conditions. Work at the FMF prior to the inception of the program provided the basic framework for the model—the dividing-streamline concept—and the focal point around which to design the field program.

Throughout the course of the CTMDP, the FMF interacted vigorously with the model developers by providing support in various ways. Early work provided direct support in planning the details and strategies of the field experiments and solidifying and testing the limits of applicability of the dividing-streamline concept. Later work included excerises of "filling in the gaps" in the field data, furthering the understanding of the typical mechanisms important to plume impaction in complex terrain and in stably stratified flows in general, and testing the ability of the laboratory models to simulate full-scale field conditions. And, as the needs arose, the FMF tested various modeling assumptions, concepts, and hypotheses and provided data for "calibration" of various parameters within the CTDM model.

Simultaneously, the FMF responded to the needs of the regulatory arm of EPA, OAQPS, by providing guidance concerning expected terrain effects and by providing a demonstration study—an example for industries to follow in conducting good-engineering-practice stack height determinations in complex terrain. Also, a broad range of supplemental studies was conducted, expanding and enlarging upon the specific requests of the OAQPS and the CTDM model developers to provide information of general use to the scientific and air pollution modeling communities. Many of the data sets generated in the course of this program have been provided to and used by various groups (nationally and internationally) in the development, testing and evaluation of complex terrain dispersion models.

The most significant contributions included (1) the conceptual framework for the mathematical model (i.e., the division of the flow-field into two regimes, a lower layer below the dividing-streamline height which flows in essentially horizontal planes around the hill, and an upper layer above the dividing-streamline height which is treated as modified potential flow over a cut-off hill) and the detailed experimental validation and establishment of limits of applicability of these concepts, (2) verification of the integral formula for the height of the dividing-streamline—this allowed computations of the dividing-streamline height under arbitrary approach-flow conditions, including shear in the approaching wind-speed profile and nonlinear temperature gradients, (3) demonstration of the extreme sensitivity of surface concentration patterns to wind direction under strongly stratified conditions, (4) measurements of plume deflections and deformations over hills in neutral flow—these permitted adjustment of the T-factors in CTDM and resulted in substantial improvements in the CTDM predictions, and (5) the introduction of the concept of "windows of excess concentration" and measurements of terrain amplification factors—these provided simple and practical methods for estimation and intercomparison of effects of terrain and source locations on maximum ground-level concentrations that may result from sources placed in the vicinities of hills.

Only the highlights of the FMF contributions to the CTMDP are contained in the present summary. The complete report provides much more detail and a comprehensive list of over 65 publications generated from the work conducted at the FMF on complex-terrain research.

The EPA author William H. Snyder (also the EPA Project Officer, see below) is with the Atmospheric Sciences Research Laboratory, Research Triangle Park, NC 27711.

The complete report, entitled "Contributions of the Fluid Modeling Facility to EPA's Complex Terrain Model Development Program," (Order No. PB 87-227 682/AS; Cost: $13.95, subject to change) will be available only from:

National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
Telephone: 703-487-4650

The EPA Officer can be contacted at:

Atmospheric Sciences Research Laboratory
U.S. Environmental Protection Agency
Research Triangle Park, NC 27711

Sandia National Laboratory

Downhole Seismic Source Available

A downhole seismic source under development at Sandia National Laboratories since the early 1980s is nearly ready for commercialization, according to its developers. The tool generates a seismic wave radiation pattern particularly useful for detecting underground fluids, including oil and gas.

The tool was developed for basic geophysical research for the Continental Scientific Drilling program, which is mapping the Earth's crust. But Sandia developers believe the source will be a valuable addition to the array of seismic tools and techniques that scientists and engineers use for evaluating known oil and gas reservoirs and exploring for new oil, gas, and geothermal energy sources. Seismic mapping for civil engineering projects is another possible application.

A Sandia crew prepares to test the prototype of the downhole seismic source in a drillhole south of Albuquerque. Detailed field testing of the prototype was done this summer near Rifle, Colorado.

A full-scale prototype of the new downhole seismic source has performed well in laboratory and field tests. It is designed to produce signals that can be detected on geophones and recorded after traveling up to 5 km (about 3 mi) from the source. (However, the tool has yet to be tested over such a range.) The geophones can be located in other drillholes or on the surface. The prototype produces signals from drillholes 6 to 12 in. in diameter and up to 2 mi deep. The sealed tool is designed to operate in dry or fluid-filled holes at temperatures up to 250°C.

Uses special piston

Seismic waves are produced by the action of a 7.5-cm (3-in.) diameter oscillating piston inside a 12.5-cm (5-in.) diameter, high-strength stainless-steel cylindrical housing. Unlike a typical automotive piston, this piston has a power stroke on each end, allowing more power to be generated in a confined space.

The piston is driven by air from a built-in pneumatic tank that supplies air to each end of the piston through a rotary valve driven by a small electric motor. The valve speed and the resulting oscillation rate of the piston are controlled by varying the motor speed, thereby allowing the signal frequency to be varied between 1 and 300 Hz. Displacing about 28 cu in., the piston can travel up to 2 in. at each end—farther at lower oscillation rates, less at higher rates.

The tool makes only a slight whirring sound because piston exhaust air is routed into another tank within the stainless-steel housing.

An electrically driven clamp at the bottom of the steel housing expands to hold the tool firmly in place against the drillhole wall or casing before the seismic source is activated. The clamp, which does not harm the drillhole or casing, also serves as the contact point where energy from the tool is transferred to the formation.

All components and functions are operator controlled through a standard seven-conductor logging cable that extends from the surface to the tool.

Prototype field tests were done in late August at the Department of Energy's (DOE) Multiwell Experiment site near Rifle, Colo. Detailed test data are still being compiled and evaluated, but preliminary results indicate that the prototype worked well. The tests generated and recorded seismic signals in drillholes more than a mile deep. The Multiwell Experiment site, which provided three readily available drillholes, is a field lab where DOE studies methods for recovering natural gas from tight (low-permeability) sands.

Supplements surface tools

Surface seismic generators have been used for years in oil and gas exploration. Using explosives or large surface-thumpers, they generate seismic waves that spread down into the subsurface where the different underground features—fluid-filled rocks, dry rocks, fractures, and structures—reflect different fractions of the energy back to the surface. These signals are recorded as geophysical

logs that can aid in detecting areas that may contain oil or gas.

Harry Hardee, supervisor of Sandia's Geophysics Division, says the downhole seismic source avoids several problems associated with surface generators: "The downhole tool delivers seismic energy more effectively because energy is not lost to surface waves and attenuation in surface-weathered layers. The tool only generates the low-frequency waves that are useful for seismic recordings, and less total energy is required because the downhole source is closer to the subsurface region being explored."

The inherent safety of the sealed tool is an attractive feature. "If you needed to map underground structure in the middle of a crowded city, you could do so easily with this new device with no fear of endangering people or property, as you might with explosive seismic techniques," Hardee says.

Several foreign patents have been issued for the device, and a U.S. patent is expected to be issued soon in the names of Hardee; Richard G. Hills, a former Sandian who is now a mechanical engineering professor at New Mexico State University; and Richard P. Striker, now retired from Sandia. Other Sandia technical staff making contributions to the source's development include Gregory Elbring, Gerald Reynolds, and Terry Steinfort.

Research and engineering funding for the tool was provided by the Department of Energy's Office of Basic Energy Sciences.

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Refer to announcement 22, No. 10

NASA Tech Brief
National Aeronautics and Space Administration

Program Reads Weather-Data Tapes From Aircraft

Data are analyzed and converted for further processing or display.

A computer program has been developed to help read and analyze the data gathered by airborne instruments for atmospheric research. By employing remote-sensing techniques, measurements of wind and wind stress can be obtained from airborne instruments in various locations and weather conditions.

The program was written to process data tapes from an airplane operated by the National Center for Atmospheric Research (NCAR). The tapes are in ½-in. (12.7-mm), nine-track, 6,250-bit/in. (2,461-bit/cm), 32-bit-word format and contain records of 19,840-bit length. There is one record per second of flight time. Each record contains samples of 98 parameters, sampled either 1 or 20 times per second.

The program reads the NCAR tape, optionally scales or averages the data, and stores (or appends) the results in a disk file. An error file is created if any records cannot be successfully unpacked and converted to real numbers. The output from this program can be used as input to statistical-analysis programs for further processing or to plotting packages for graphical representation of the data.

This program is written in FORTRAN 77 for interactive execution and has been implemented on a DEC VAX-series computer operating under VMS. The program was developed in 1984.

This program was written by Mike Carlton and Carl A. Friehe of the University of California for **NASA's Jet Propulsion Laboratory**. *NPO-16744 /TN*

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Physical Sciences

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426 Convective Evaporation of Sprayed Liquid — The behavior of clusters of drops is analyzed.

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428 Predicting Visible Range of an Object — The relative angles of light sources and object orientation are taken into account.

429 Swivel Joint for Liquid Nitrogen — The joint is compatible with hard foam insulation.

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433 Calculating Thermodynamic and Transport Properties of Fluids — A computer program incorporates a van der Waals equation and correction tables.

434 Improved General Chemical-Kinetics Program — More computational power is brought to bear on complicated, homogeneous ideal-gas reactions.

435 Star-Tracker Computer Program — Image-analyzing systems can be aimed to high precision.

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436 A Low-Volume Insert for Solid-State Magic Angle Spinning NMR of Small Samples

437 IMAGESystem — Improved imaging and data handling for gel electrophoresis.

438 Apparatus for Ultrasonic Nebulization (Licensing Opportunity)

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Other Items of Interest

409 Advances in Thermoelectric Materials — Rare-earth chalcogenides and boron-rich borides show promise.

413 Polyphenylquinoxalines Containing Alkylenedioxy Groups — Better processability is achieved through the lowering of glass-transition and melt temperatures. (Licensing Opportunity)

414 Thermosetting Fluoropolymer Foams — Uses include coatings, electrical insulation, and structural parts. (Licensing Opportunity)

417 Slow Neutron Reflectometer (POSY II) — New application of neutron reflection techniques measures interdiffusion of polymers.

Soft X-Ray Lasers Under Development

Researchers at the Naval Research Laboratory (NRL) have demonstrated lasing at soft X-ray wavelengths in copper and germanium plasmas that were heated by a high-power infrared laser.

In recent experiments, Tong Nyong Lee, Edgar McLean, and Raymond Elton of the Plasma Physics Division, reported lasing at various wavelengths in the interval 196-286 Angstroms, using relatively simple, thick slab targets with the assistance of James Ford and Nicholas Nocerino.

The scientists state that although the present output power of these NRL lasers is rather modest (a few kilowatts in a pulse about one-billionth of a second long), their hope is that further improvements will take the power up to megawatts, where many military and civilian applications requiring short laser wavelengths can be realized. These applications include X-ray lithography and microscopy, X-ray holography and flash radiography laser in a high-temperature plasma created from an ultrathin foil of selenium that was heated by a high-power glass laser.

The NRL researchers say that they built upon this early result, obtaining similar laser gain using a much simpler target (a thick slab instead of an ultrathin foil), and a much lower-power glass laser heating source (approximately one-tenth the power level). In addition, strong lasing lines were seen that had been predicted but not previously observed.

The team states that to generate the X-ray lasing light, NRL's Pharos III neodymium glass laser was operated at an infrared wavelength, a pulse energy up to 500 joules, and a pulse duration of two-billionths of a second.

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NASA Tech Brief
National Aeronautics and
Space Administration

Convective Evaporation of Sprayed Liquid

The behavior of clusters of drops is analyzed.

A theoretical model has been developed to analyze the behavior of both dense and dilute clusters of evaporating liquid drops in gas flows. The model is particularly useful in the search for methods of controlling the evaporation, ignition, and combustion of fuel sprays.

The analysis is based on a cluster of drops, all of the same size, uniformly distributed in a cluster volume, V_c, which is embedded in a gaseous control volume, V. The drops are treated as moving with respect to the gas, but not with respect to each other. Each drop is considered to be surrounded by an imaginary sphere of influence, the radius of which is half the distance between adjacent drops; the ensemble of the spheres of influence and the spaces between them constitute V_c.

The quiescent evaporation of each drop within its sphere of influence is modeled by quasi-steady convective/diffusive differential equations for species and heat. These equations are coupled to the equations for the nonuniform temperature within the drop through the boundary conditions at the drop surface. The solutions of these equations are used in an integral set of equations that describe heat, mass, and species conservation over the entire V_c, and the global equation of state completes the formulation for the quiescent condition. Convective evaporation is described with the help of a previously developed correlation between the quiescent evaporation rate, the evaporation rate in convective flow, and the Reynolds number. In this case, the Reynolds number is based on the drop radius and the relative velocity between the cluster of drops and the gas.

The equation for the conservation of momentum in V treats the drop cluster and the gas as two interpenetrating fluids. The transfer of momentum between the drops and the gas is assumed to occur through evaporation, fluid-flow interaction that can be expressed in the form of a drag coefficient, and small pressure gradients: this splitting enables the model to yield the correct limits in the case of no evaporation, no slip (zero relative velocity), or quiescent ambient gas.

Calculations for a spray of n-decane in air revealed several distinctive evaporation regimes at different fuel/air ratios. Very dense clusters were found to evaporate in a diffusion-controlled regime, while very dilute clusters were found to evaporate in a convection-controlled regime. Between these extremes is a convection/diffusion regime where both phenomena influence the lifetime of the drop cluster. These results are insensitive to the drag model: three different drag models showed less than 10-percent variation in the evaporation time.

The effects of important parameters were investigated in the various evaporation regimes. The initial relative velocity was found to be a weak control parameter for both dense and dilute clusters. The variation of the evaporation time with the initial ambient temperature is basically the same for both dense and dilute clusters. For both dense and dilute clusters the internal drop temperature relaxes quickly to a nearly uniform condition, but transients persist throughout the drop lifetime.

The drop lifetime in a dilute cluster depends weakly on the initial drop temperature, while for dense clusters the dependence is weak in the higher-temperature regime and strong in the lower-temperature regime. For a given air/fuel mass ratio, the evaporation time of a dilute cluster is very insensitive to the fraction of the fuel mass that is initially in vapor form, but the evaporation time of a dense cluster decreases linearly with an increase in the initial fuel-vapor fraction.

This work was done by Josette Bellan and Kenneth G. Harstad of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "Analysis of the Convective Evaporation of Dense and Dilute Sprays," NPO-16955 /TN*

FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD 21240; (301) 621-0100 Ext. 241*

REFER TO THE NUMBER LISTED AT THE END OF THIS ARTICLE

NASA Tech Brief
National Aeronautics and Space Administration
Ames Research Center, Moffett Field, California

Licensing Opportunity

Air Revitalization Using Superoxides

$Ca(O_2)_2/KO_2$ pellets are superior to KO_2 pellets for air revitalization.

Pellets made from powder mixtures of potassium superoxide, KO_2, and calcium superoxide, $Ca(O_2)_2$, have proven markedly superior to pellets of pure KO_2 for adding O_2 to and removing CO_2 from an atmospheric-pressure flow of humidified CO_2 in He. Superoxides have been used extensively to supply O_2 and scrub CO_2 in a variety of ambient-pressure life-support applications — including portable self-contained breathing apparatuses, spacecraft, and undersea submersible craft — and are attractive candidates for high-pressure air-revitalization applications because of their high O_2-storage density and high CO_2-absorption capacity and because of the potential simplicity of the total O_2-delivery/CO_2-scrubbing system.

Potassium superoxide releases O_2 and absorbs CO_2 through the following reactions:

1. $2KO_2 + H_2O \rightarrow 2KOH + 3/2\ O_2$
2. $2KOH + CO_2 \rightarrow K_2CO_3 + H_2O$
3. $KOH + CO_2 \rightarrow KHCO_3$

Unfortunately, upon exposure to the concentrations of H_2O and CO_2 existing in exhaled human breath, KO_2 tends to form fused, hydrated-hydroxide/carbonate coatings of low gas permeability on the exterior of the chemical granules. Once this product layer is formed, it limits the diffusion of H_2O and CO_2 reactants to the unreacted core of the KO_2 and results in poor utilization of the available O_2 and of the CO_2-scrubbing capacity. Moreover, the presence of the hydrated-hydroxide coating in conjunction with the exother-

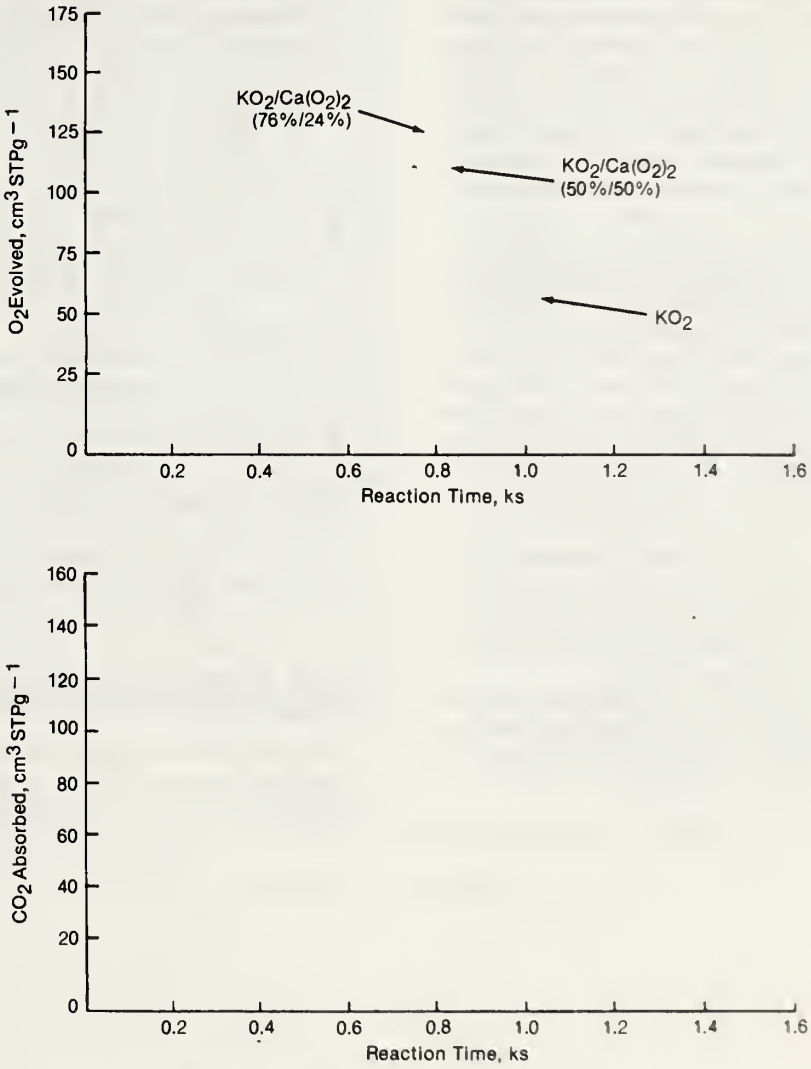

Figure 1. **Under Identical Conditions** at atmospheric pressure, about 2 times the amount of oxygen was evolved and about 3 times the amount of CO_2 was absorbed by $KO_2/Ca(O_2)_2$ pellets as by KO_2 pellets.

micity of reaction promotes intergranule fusion, making sections of the packed bed unavailable for reaction with the exhaled gas. The utilization of available O_2 is typically only 50 to 80 percent for KO_2 in portable breathing apparatuses. If reuse of a breathing apparatus is desired, the fusion of the superoxide bed also makes it difficult to remove the expended chemical from the breathing canister.

In 1-atm (0.1-MPa) flow tests, the deleterious coating effect encountered with KO_2 was alleviated using mixtures of KO_2 and $Ca(O_2)_2$ containing 24 or 50 weight percent of $Ca(O_2)_2$, without a significant sacrifice in the overall available O_2 and in the CO_2-scrubbing capacity (see Figure 1): the product coating on the superoxide-mixture pellets was permeable to H_2O and CO_2 reactants and was also hard and nonfusing. The expended superoxide material could be easily removed from the breathing canister: hence, re-use of the breathing device would be possible.

When individual pellets of 50 percent KO_2 and 50 percent $Ca(O_2)_2$ were reacted with humidified CO_2 in He at 10 atm (1 MPa), the rates of O_2 evolution and CO_2 absorption were one-third to one-eighth that exhibited by similar samples tested at 1 atm (0.1 MPa) (see Figure 2). It has been postulated that this drop in reactivity under hyperbaric conditions is caused principally by the decrease in the bulk diffusivity of the H_2O and CO_2 reactants in the high-pressure He, because the reactivity of the pellet was restored when the pressure was decreased from 10 atm (1 MPa) to 1 atm (0.1 MPa) while the other reaction conditions were held constant.

This work was done by Theodore Wydeven of **Ames Research Center** *and by Peter C. Wood and L. A. Spitze of San Jose State University.*

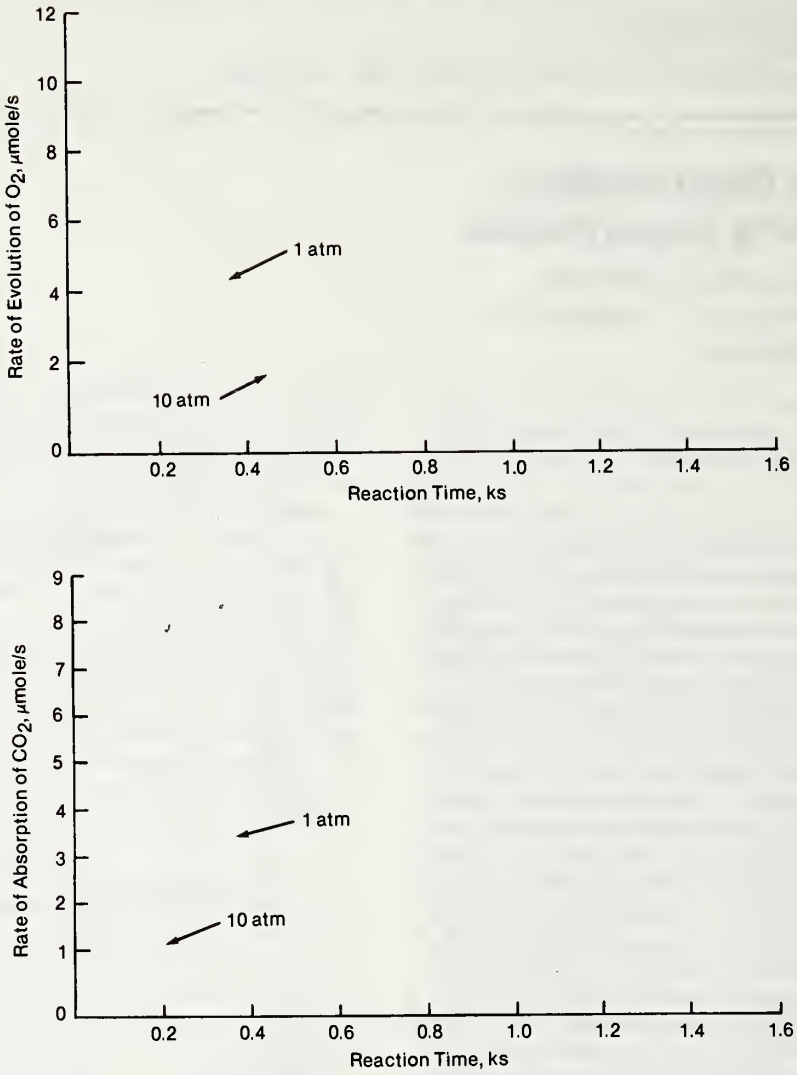

Figure 2. The **Rates of O_2 Evolution and CO_2 Absorption** are much less at 10-atm (1-MPa) pressure than at 1-atm (0.1-MPa) pressure.

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Ames Research Center Refer to ARC-11695. /TN

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NASA Tech Brief
National Aeronautics and
Space Administration

Predicting Visible Range of an Object

The relative angles of light sources and object orientation are taken into account.

A report and supplementary materials present a method for estimating the maximum distance at which the Spartan free flyer can be seen by star trackers on the Space Shuttle. The ability to detect the Spartan, or another object, depends on the brightness of the object relative to that of other visible sources. The brightness, and consequently the visible range, is calculated by using a simplified model of the object as a reflector, taking into consideration the orientation of the object and the predicted relative positions of the Shuttle and the Sun.

The Spartan reflector model is a rectangular parallelepiped having a diffuse reflectance of 0.05 on one of the end faces and 0.82 on all of the other faces. The model is considered to be illuminated by solar radiation and by light reflected from the Earth. A conservative average Earth albedo of 0.30 is adopted, and the illumination of the Spartan by the reflected light is approximated by summing the reflections toward the Spartan from finite Sun-illuminated surface elements of the Earth visible from the Spartan.

Illuminated by the combined direct and Earth-reflected solar radiations, the Spartan reflector model becomes, via its own reflectivity, a model light source itself. The intensity of this Spartan source varies with direction of observation, and its intensity in the Shuttle direction determines the desired visible range. The light reflected into the Shuttle star trackers from each Spartan face visible from the Shuttle is calculated from the intensity of its combined illumination, its reflectivity, and its angle to the Shuttle/Spartan line.

The angles for the photometric calculations are obtained from the fundamental geometric relationships among the positions of the Sun, Earth, Shuttle, and Spartan, and from the orientation of the Spartan. The inputs for the angle calculations are obtained from the ephemerides of the Sun and the Shuttle, and from the anticipated schedule of Spartan maneuvers.

The working range is defined as the distance at which the Spartan brightness is at least third stellar magnitude, the level needed for reliable detection by the star trackers. Because of the uncertainties in predicting actual Spartan/Shuttle distances, the visibility-prediction problem is formulated to compute the working range from the other variables. In practical applications, a series of computed ranges covering all or a part of a Spartan free flight can be plotted against time and compared to actual range values or limits to determine the usefulness of optical tracking during the flight.

This work was done by Joseph C. King of **Goddard Space Flight Center**. *To obtain a copy of the report, "Continuous Prediction of Spartan Visibility from Orbiter Over Modeled Free-Flight Mission" and the summaries "Optical Tracking" and "Method for Predicting Free-Flyer Visibility from Shuttle," GSC-13078 /TN*

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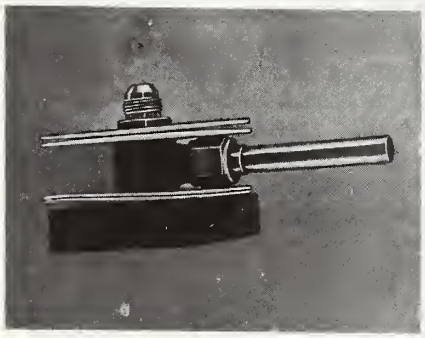
NASA Tech Brief
National Aeronautics and Space Administration
Lyndon B. Johnson Space Center, Houston, Texas

Swivel Joint for Liquid Nitrogen

The joint is compatible with hard foam insulation.

A swivel joint allows a liquid-nitrogen pipe to rotate through an angle of 100° with respect to a mating pipe. The joint functions without cracking the hard foam insulation on the lines.

The joint carries liquid nitrogen for cooling from the outside to panels on the inside of a hinged vacuum-chamber door (see Figure 1). The joint rotates when the door is opened or closed, without stressing the brittle insulating foam on the pipes and without significant leakage of nitrogen from the 40-lb/in^2 (280-kPa) pressurized line.



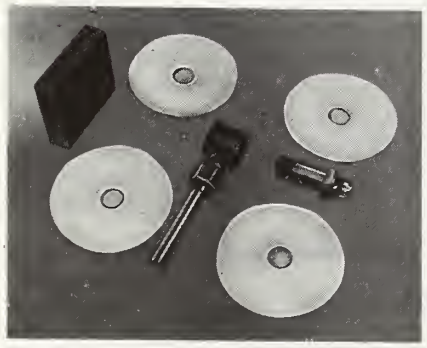


Figure 2. The **Pipe Joint Rotates** on disks so that mechanical stress is not transmitted to the thick insulation on the pipes. The inner disks ride on the fixed outer disks. The disks also help to seal the pressurized liquid nitrogen flowing through the joint.

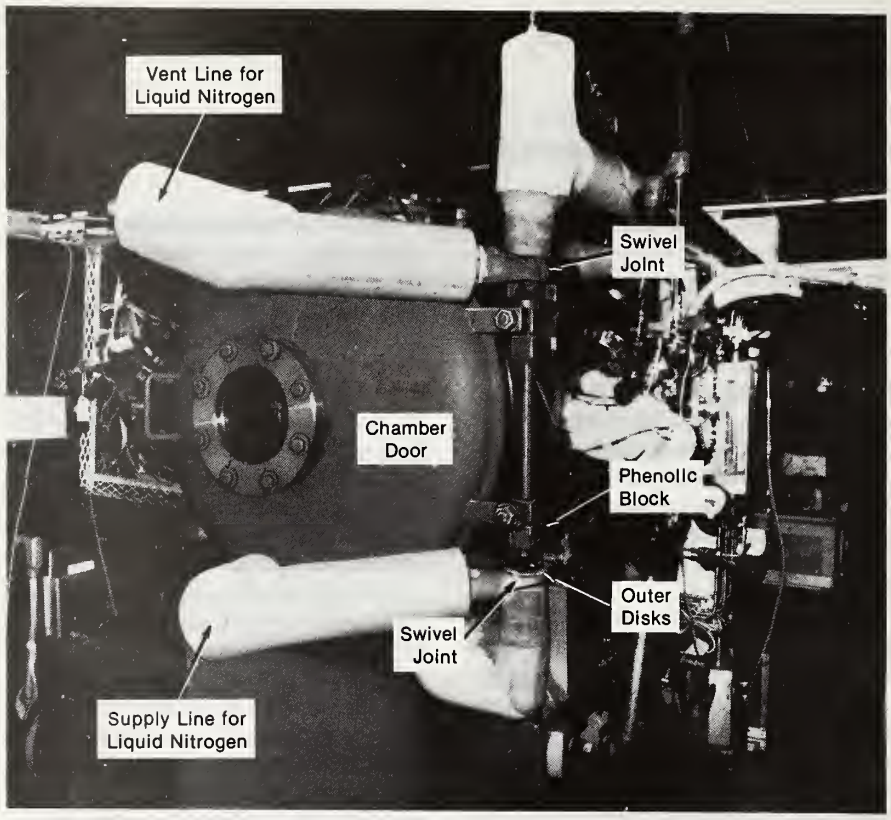


Figure 1. The **Pipe Joint Is Placed on the Hinge Line** of the door, enabling liquid nitrogen to flow between rigid, insulated pipes on the door and on the frame.

The swivel joint and pipes replace a flexible hose, which was unsatisfactory for several reasons. The soft foam insulation cracked after repeated opening of the door. Heat penetrating the cracks caused a significant loss of the cryogenic liquid. Frost accumulated in the cracks, eventually melted, and formed puddles on the floor. While the chamber was being filled or purged, the hose vibrated excessively.

The joint includes a stainless-steel bolt-and-connector combination of a standard type used in hydraulic systems (see Figure 2). The movable connector turns on the fixed bolt. Two pairs of large-diameter polytetrafluoroethylene disks — one pair at the top of the connector and one at the bottom — allow smooth, low-friction rotation to isolate the insulation from stress.

This work was done by James F. Milner of Rockwell International Corp. for **Johnson Space Center**. *MSC-21160 /TN*

FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD 21240; (301) 621-0100 Ext. 241*

REFER TO THE NUMBER LISTED AT THE END OF THIS ARTICLE

NASA Tech Brief
National Aeronautics and Space Administration
NASA's Jet Propulsion Laboratory, Pasadena, California

Licensing Opportunity

Tunable Dual Semiconductor Laser

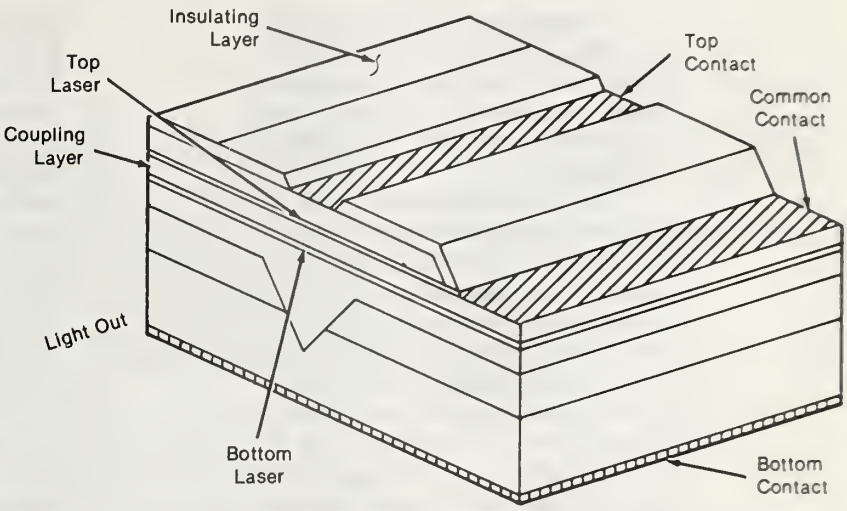
Parallel lasers interact in shared space to alter output wavelength.

The light produced by a near-infrared semiconductor laser can be tuned over a range of 3 nm by a parallel laser directly below it in the same chip. The tunable laser will be useful in optical communication, in which narrow-band interference filters are used widely. The passband of such filters tends to change with age, and the fixed wavelength of light generated by a laser may no longer precisely match the wavelength of light transmitted by the filter. As much as 60 percent of the output power of the laser may be lost on account of mismatch with the filter. With the new tunable device, the output wavelength may be changed to match the changing wavelength of peak filter response. Such tunable sources can also be useful in optical communications systems employing wavelength-division multiplexing.

The new device consists of two stripe lasers in an aluminum gallium arsenide chip (see figure). The parallel stripes are close enough so that light from the lower laser is coupled into the upper laser and vice versa. The lasers are operated by low-duty-cycle current pulses. The lasing threshold of each is about 100 mA. The currents are controlled independently.

The current in the top laser is adjusted so that it is above the threshold value, and the laser produces a beam of coherent light at about 880 nm. The current in the bottom laser is kept below the threshold. As the current in the bottom laser is increased, the wavelength of the light from the top laser decreases. Moreover, the output is single-mode light rather than the usual multimode radiation and has a narrower spectrum than light from single semiconductor lasers.

Changing the current in the bottom laser apparently changes the complex dielectric constant of that device. This change in turn alters the resonance condition of the combined cavities of the two lasers and thereby alters the output wavelength.



The **Top Laser Emits Light**, the wavelength of which is controlled by the bottom laser. Current to the top laser is applied through the top and common contacts, and current to the bottom laser is applied through the common and bottom contacts.

When the current in the bottom laser is increased above the threshold level, that device also starts lasing. The chip then produces two laser beams at different wavelengths.

The chip is made by a process that includes two stages of liquid-phase epitaxial growth. First, an n^+ gallium arsenide layer is grown on a p^+-type, zinc-doped gallium arsenide substrate. A groove is etched through the layer and into the substrate. In the second epitaxial step, five layers of differing composition are grown to delineate the two layers. Top, common, and bottom electrical contacts are then deposited on the chip.

This work was done by Seiji Mukai, Eli Kapon, Joseph Katz, Shlomo Margalit, and Amnon Yariv of Caltech for **NASA's Jet Propulsion Laboratory**.

Title to this invention has been waived under the provisions of the National Aeronautics and Space Act [42 U.S.C 2457(f)], to Caltech. Inquiries concerning licenses for its commercial development should be addressed to

Edward Ansell
Director of Patents and Licensing
Mail Stop 301-6
California Institute of Technology
1201 East California Boulevard
Pasadena, CA 91125
Refer to NPO-16374, ITN

Jet Propulsion Lab.
4800 Oak Grove Drive
Pasadena CA 91109

Technology Utilization Mgr.: Norman L. Chalfin
Mail Stop 156-211
(818) 354-2240

NASA Resident Technology Utilization Officer: Gordon S. Chapman
Mail Stop 180-801
(818) 354-4849

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REFER TO THE NUMBER LISTED AT THE END OF THIS ARTICLE

Computer Program Calculates Long Wavelength Propagation

A computer program called the Segmented Waveguide Program obtains waveguide mode solutions for very low frequencies and low frequencies (VLF/LF).

The program, developed by the Naval Ocean Systems Center, San Diego, California, allows for multiple homogeneous segments to be specified, allowing for consideration of variations in the earth-ionosphere waveguide. Path geometry and geophysical parameters can be computed by the program. Ionospheric disturbances due to man-made or naturally occurring events can also be modeled through the use of this program.

Essential features of this program include:

- Automatic segmentation of the propagation path
- Allowance for presegmentation of the propagation path
- Allowance for variation of the ionosphere along the path

The program operates on propagation paths defined by a transmitter location and either a direction or a receiver location. A propagation path is defined as the great circle on a spherical earth. Variation of the geophysical parameters are to be expected along realistic paths. The diurnal condition in large part determines the significance of the other parameters. For instance, under daytime conditions the effect of variation of the geomagnetic field along a path is usually not significant to the resulting mode parameters. The program incorporates routines for calculating the parameters of the geomagnetic field and for selecting the ground conductivity at any point on the earth's surface.

For Additional Information:

Backup material on this effort is available from:

Navy Domestic Technology Fact Sheet
Reader Reply Service,
Code E211,
Naval Surface Weapons Center,
Dahlgren, VA 22448-5000
(703) 663-8921

Refer to 121101/TN

Calculation of Multicomponent Convective Diffusion Deposition

A computer program calculates rates of deposition by vapor or by small particles.

A wide variety of engineering concerns, including the chemical coating of metals, solid-state electronics, filtration, icing of aircraft, and the corrosion and fouling of gas-turbine blades and heat exchangers, involves the capture of vapor and particles. A computer program that embodies a comprehensive but tractable theory of rates of convective diffusion deposition has been developed on the basis of the assumption of a multicomponent, chemically-frozen boundary layer.

The theory makes full use of the available information on transport coefficients and properties. It is not only applicable under conditions of transport of multicomponent vapors (e.g., chemical-vapor deposition) but is also capable of simultaneously calculating the transport of particles, provided that the particles are small enough to be considered heavy molecules. The code is being used to interpret experiments in the deposition of sodium sulfate as related to hot corrosion.

The program is written in FORTRAN IV for use on an IBM computer.

This program was written by Suleyman A. Gokoglu of Analex Corp. and Daniel E. Rosner and Bor-Kuan Chen of Yale University for **Lewis Research Center**.

LEW-14366 /TN

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Calculating Thermodynamic and Transport Properties of Fluids

A computer program incorporates a van der Waals equation and correction tables.

The accurate computation of the thermodynamic and transport properties of fluids is a necessity for many engineering calculations. The FLUID program was developed to calculate the thermodynamic and transport properties of pure fluids in both the liquid and gas phases. Properties are calculated by use of a simple gas model, empirical corrections, and an efficient numerical interpolation scheme. FLUID produces results that agree very well with measured values. FLUID is much faster than older, more complex programs developed for the same purpose.

A van der Waals equation of state is used to obtain approximate state values. These values are corrected for the effects of real gases by model correction factors obtained from tables based on experimental data. These tables also compensate accurately for the special circumstances that arise from phase transitions. Values of viscosity and thermal conductivity are computed directly from tables. Interpolation within tables is based on Lagrange's three-point formula. A set of tables must be generated for each fluid.

FLUID currently contains tables for nine fluids, including dry air and steam. The user can add tables for any fluid for which adequate data on thermal properties are available. The FLUID routine is structured so that it can be incorporated easily into engineering programs.

The IBM-360 version of FLUID was developed in 1977. It is written in FORTRAN IV and had been implemented on an IBM 360 with a central memory of approximately 500K bytes. The IBM-PC version of FLUID is written in Microsoft FORTRAN 77 and has been implemented on an IBM PC with a memory of 256K bytes. The IBM-PC version of FLUID was developed in 1986.

This program was written by Margaret P. Proctor of **Lewis Research Center** *and Mark D. Klem of the U.S. Air Force.*
LEW-14418 /TN

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Improved General Chemical-Kinetics Program

More computational power is brought to bear on complicated, homogeneous ideal-gas reactions.

A new general chemical-kinetics code, GCKP84, has been developed to compute the progress of many types of complex gas-phase chemical reactions. This new code replaces the original GCKP code and offers greatly improved efficiency, additional capabilities, and greater convenience.

The original GCKP computed the progress of a general complex, homogeneous, gas-phase reacting system. The system was assumed to be adiabatic, and the reaction could be in a batch or in one-dimensional frictionless flow. Shock-tube kinetics and equilibrium combustion models were also included in the code. Any chemical system could be used if thermodynamic data for the species and the chemical-reaction mechanism (including rate constants) were known.

The new code, GCKP84, has the following seven new capabilities and convenient features:

1. Heat transfer between any reacting system and its surroundings can now be considered.
2. The well-stirred-reactor model is included.
3. A new implicit numerical-integration technique is used for greatly increased speed in integrating "stiff" differential equations. The speed of integration is increased by a factor of 10 to 20 over that of GCKP, while maintaining the same accuracy.
4. The new code can use several additional types of reaction processes, including photochemical reactions and reactions of activated species.
5. The input for combustion problems is simplified.
6. Rocket-performance parameters can be computed for any flow-expansion problem.
7. A well-stirred reactor followed by a normal flow reaction can be computed as a single case.

The new code is written in FORTRAN IV and was developed on the IBM 370/3033 computer.

This program was written by David A. Bittker and Vincent J. Scullin of **Lewis Research Center**. *LEW-14216 /TN*

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Star-Tracker Computer Program

Image-analyzing pointing systems can be aimed to high precision.

The star-tracker program, STRACKER, was developed to solve algorithm-design problems for area-array tracking and pointing systems operating at accuracies of 0.001 to 0.01 picture element (pixel). Trackers and pointers of this accuracy are primarily required for the pointing of astronomical instruments. STRACKER includes auxiliary programs for reformatting point-spread data from the commercial ACCOS V lens-design program. Other optical-analysis program data can be reformatted by use of the utility routines included in the STRACKER package.

STRACKER calculates a simple centroid estimation of an arbitrary point-spread function supplied by the user. It then calculates a set of correction polynomials to best-fit the calculated centroid to the actual centroid as the actual centroid is moved over a pixel. Maximum and root-mean-square errors are calculated for all polynomials.

STRACKER displays the polynomial values and a pixel-error map showing, in two dimensions, the deviations from perfect pointing. STRACKER can also calculate the field variation of a set of point-spread functions, and local corrections thereof, distributed in an image field. The program is menu-driven and prompts the user for all required input. Options include the calculation, storage, and recall of sets of polynomials and the generation of plots of zones, full-field errors, and individual field-point errors.

STRACKER is written in FORTRAN 77 for interactive execution and has been implemented on a PRIME 550 computer operating under PRIMOS 19.1.6 with a central-memory requirement of approximately 250K bytes. STRACKER supports Tektronix 4025 and 4107 graphics terminals. The program was developed in 1986.

This program was written by Thomas Glavich of Caltech for **NASA's Jet Propulsion Laboratory**. *NPO-16862 /TN*

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US Army Fact Sheet

A Low Volume Insert for Solid-State Magic Angle Spinning NMR of Small Samples

Recently, several new rotor insert designs for magic angle spinning (MAS) NMR have been described. These inserts were designed primarily for sampling of air and moisture sensitive materials without compromising the angular stability needed for MAS. While the utility of rotor inserts has been aptly demonstrated, currently no reports exist of an insert specifically designed for handling small (10-20 mg) samples. It might be expected that the resulting loss of signal-to-noise coupled with increased acquisition time for such small samples would be unacceptable. However, many samples are available only in small amounts due to scarcity, expense, or regulatory control. Some examples are drugs and other controlled substances, biological materials, micro-scale synthesis products, and materials with labeled nuclei.

Two simple rotor insert designs for accomodating small samples within a standard double air bearing MAS rotor were developed. These easily machined ceramic inserts were compared to standard rotors packed completely with samples or with silica gel-diluted samples of adamantane and glycine. A disc-shaped sample cavity gave better signal-to-noise than a cylindrically-shaped one for comparable sample size and number of scans, and gave the narrower peak widths than even the full rotor. The inserts are inexpensive and easy to use while facilitating high-speed rotor spin-up and recovery of the non-contaminated samples.

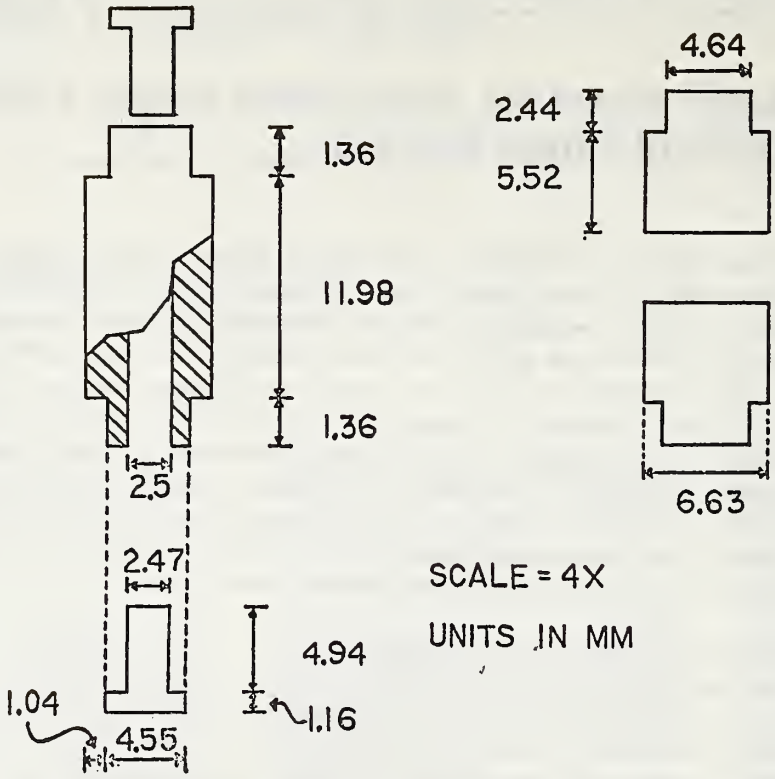
A potentially valuable application of the insert approach is in the analysis and identification of forensic samples, especially controlled substances and new "designer" drugs. Routine use of the inserts in analytical, organic and most importantly, in polymer chemistry can greatly facilitate research efforts when only small samples are available of materials that were difficult or expensive to produce.

FOR ADDITIONAL INFORMATION:

A full description of this activity is contained in a backup report which may be purchased from NTIS, Springfield, VA 22161; (703) 487-4650.

NTIS order number: AD-A184359/NAC
Price code: A02

To discuss this effort further, contact Lon Mathias, University of Southern Mississippi, Polymer Science Department, Southern Station Box 10076, Hattiesburg, MS 39406-0076; (601) 266-4868.


1.36
11.98
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6.63
SCALE = 4X
UNITS IN MM

Brookhaven National Laboratory

IMAGESystem

Improved Imaging and Data Handling for Gel Electrophoresis

An electronic imaging system has been developed as an alternative technique to photography for gel electrophoresis analysis. It is applied for quantitating the distribution of fluorophore stained DNA or other biopolymers. The key components are a charge coupled device (CCD) TV camera, a video frame grabber, a special designed interface and a computer. The method is useful for studying damage in DNA that is available only in small quantities (only 50 nanograms are required) and that cannot be labeled with radioactive tracers.

STAGE OF DEVELOPMENT

A system exists which can be the basis for development of a commercial prototype. Approximate cost is $30,000 for a system, excluding the host computer.

APPLICATIONS

IMAGESystem acquires a complete two-dimensional image of a gel. With additional software it can thus be used to analyze gels in which a sample has been dispersed along two orthogonal directions.

PATENT STATUS

Patent Pending

PUBLICATIONS

S.E. Freeman, A.D. Blackett, D.C. Monteleone, R.B. Setlow, B.M. Sutherland, J.C. Sutherland, "Quantitation of Radiation-, Chemical-, or Enzyme-Induced Single Strand Breaks in Nonradioactive DNA bu Alkaline Gel Electrophoresis: Application to Pyrimidine Dimers", Analytical Biochemistry 158, 1986, pp. 119-129.

J. C. Sutherland, B. Lin, D.C. Monteleone, J. Mugavero, B.M. Sutherland, J. Trunk, "Electronic Imaging System for Direct and Rapid Quantitation of Fluorescence From Electrophoretic Gels: Application to Ethidium Bromide Stained DNA", Analytical Biochemistry (in the press).

Additional Information

W. Marcuse, Office of Research and Technology Applications, Brookhaven National Laboratory, Upton, New York 11973; (516) 282-2103. Refer to DOE/BNL-32/TN.

Department of Energy

Technology Application

Ames Laboratory

Apparatus for Ultrasonic Nebulization

A new and improved ultrasonic nebulization apparatus was developed for generating aerosols suitable for use in atomic spectroscopy, simulation of industrial and environmental atmospheres, for inhalation therapy or exposure, and for determination of filter efficiency. The invention solves the problem of obtaining lower limits of detection for analysis methods that employ nebulization of liquids. The problem is solved by providing greater efficiency of nebulization, with stability and freedom from attack by solutions. This technology improves upon earlier devices which had insufficient detecting power and were subject to performance degradation caused by chemical attack.

FOR ADDITIONAL INFORMATION:
Daniel E. Williams
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and Technology Application
119 Office and Laboratory Building
Iowa State University
Ames, Iowa 50011
(515) 294-2635
Refer to Patent 4,109,863/TN

EXPLOSIVES SENSOR

Key words: Explosives; organic compounds; chemicals; detection device

Researchers at ORNL have developed a compact, high-speed explosives sensor. This supersensitive device is designed specifically to detect the organic nitrogen-oxygen compounds that are the building blocks of explosives. It is also suitable for monitoring airborne pollution, hazardous wastes, drugs, and other chemical compounds.

The explosives sensor has been designed to function automatically under computer control. Built-in software carries out the analysis and triggers an alarm when explosives are detected. It can analyze air samples taken in real time, as well as samples gathered from remote locations, in a few seconds. Special training is not required to operate the sensor, and it can be used in conjunction with existing X-ray and metal-detecting devices.

The explosives sensor is a miniature version of laboratory mass spectrometer (Fig. 1). Its small

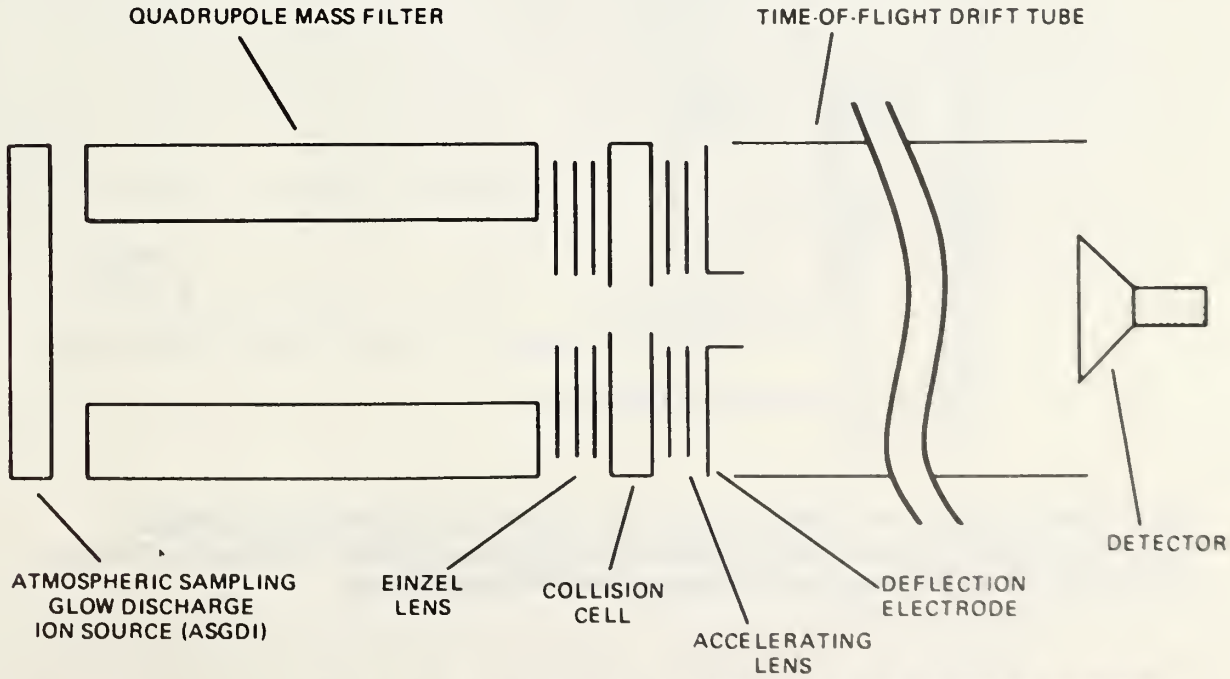

Fig. 1. Schematic of the explosives sensor. Ions generated by the ASGDI source pass through the quadrupole mass filter. They are focused by the Einzel lens into the collision cell and accelerated by the accelerating lens through the time-of-flight drift tube toward the detector.

size, low maintenance requirements, and high accuracy are possible because of its unique Atmospheric Sampling Glow Discharge Ionization (ASGDI) ion source (Fig. 2). The ASGDI source can run for months without maintenance because, unlike conventional ion sources, it lacks the discharge electrode or filament that requires frequent replacement. It is also ten times more sensitive and has a much greater dynamic range than conventional sources. Also, because it operates at reduced pressure, it can identify more ions and ions of differing stabilities.

Additional information:

National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road
Springfield, VA 22161

S. A. McLuckey et al., *Detection of Vapors of Flammable Liquids in Air by Atmosphere Sampling, Mass Spectrometry/Mass Spectrometry Progress Report: March 31, 1987,* ORNL/TM-10506, Oak Ridge National Laboratory (August 1987).

G. L. Glish et al., "Improved Performance of a Tandem Quadrupole/Time-of-Flight Mass Spectrometer," *Anal. Instrum.* **16,** 191-206 (1987).

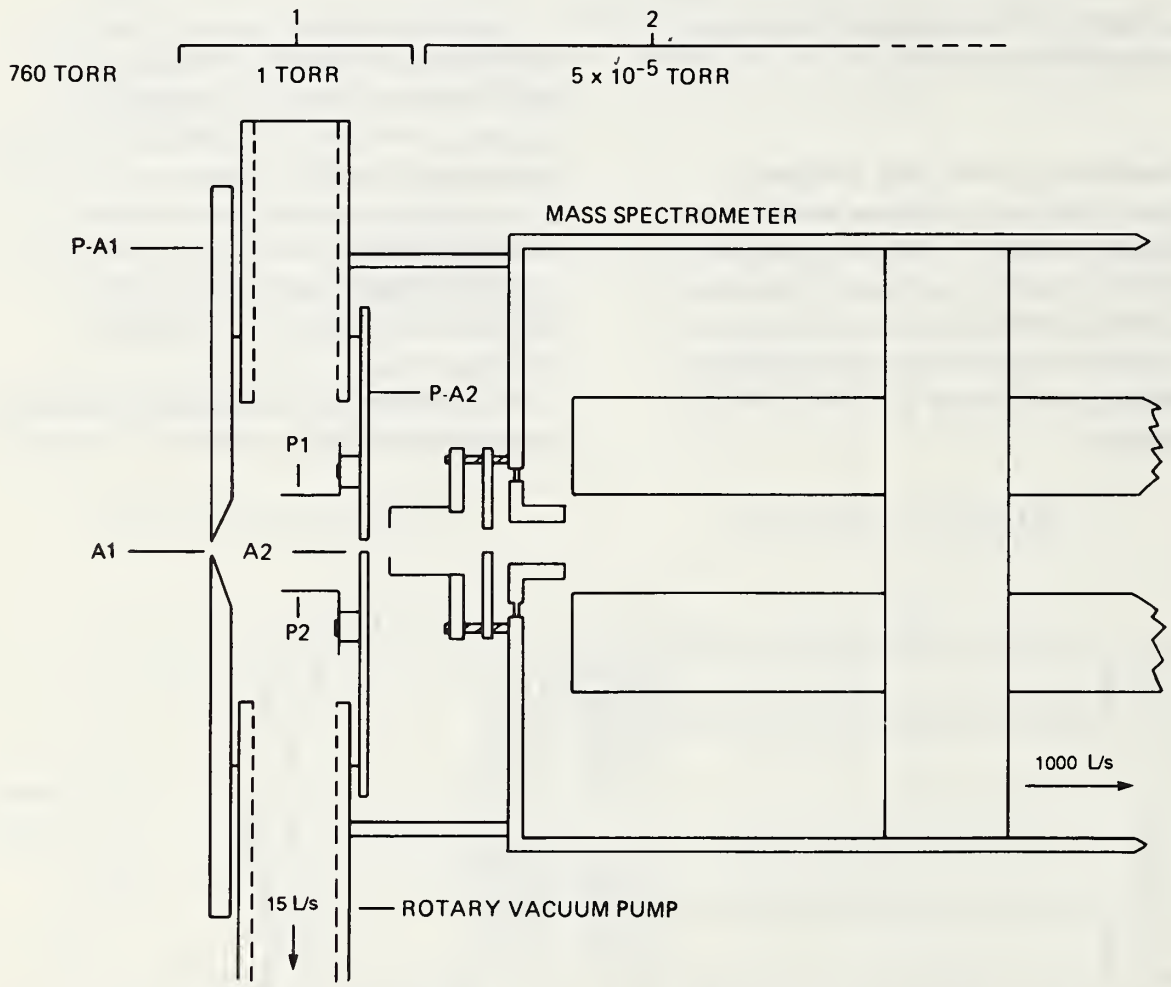

Fig. 2. Schematic diagram of the ASGDI ion source. The sample is drawn into the ion source through aperture A1. Ionization occurs because of a difference in electrical potential between either plates P-A1 and P-A2 or plates P1 and P2. Ions enter the quadrupole mass filter via aperture A2.

Department of Energy

Technology Application

Ames Laboratory

Sulfide Detection Apparatus

An invention provides a method of chemiluminescently determining sulfide which can be continuously run in order to monitor industrial reactions which might be poisoned by sulfide. These sulfides are detected by chemical reaction in the gas phase. Excess chemical energy results in emission of light that is characteristic of the sulfide. The technique allows for the monitoring of low concentrations. This invention improves existing technology due to the absence of signals from other components in the atmosphere and because it permits continuous monitoring. It is ready for incorporation into a complete sulfide-monitoring system.

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Refer to Patent 4, 634, 574/TN

Transportation & Components

Software

441 Numerical Simulation for Supersonic Inlets — Flows are calculated for realistic engine-inlet conditions.

442 Simulation of the Internal-Combustion Engine — This program adapts to the available information about a particular engine.

Other Items of Interest

401 Effects of Plastic Bead Paint Removal on Properties of Aircraft Structural Materials

Numerical Simulation for Supersonic Inlets

Flows are calculated for realistic engine-inlet conditions.

The analytical study of large-scale transient flows in supersonic inlets and interactions of inlet flows with engine flows is of primary importance to the design and control of inlets. The optimum design of an inlet, its associated auxiliary air systems, and the inlet-control system is based on an understanding of the effects of flow transients on the history of the inlet flow and the attendant effect on the control and performance of the inlet. The computer code LAPIN (large-perturbation inlet) was developed to analyze the large-perturbation, transient-flow fields in supersonic inlets.

LAPIN is a robust, quick-running code capable of solving unsteady quasi-one-dimensional, inviscid-flow problems in mixed subsonic and supersonic regimes for inlets. Its approach is based upon a quasi-one-dimensional, inviscid, unsteady formulation that includes engineering models of unstart/restart, bleed, bypass, and geometrical effects. The numerical solution of the governing time-dependent equations of motion is accomplished through a shock-capturing, finite-difference algorithm. A few of the important numerical features included in the code are the following:

- Implicit Solution Algorithms — The Beam and Warming and the MacCormack implicit methods have been included to provide fast solutions under slow transients or under time-asymptotic conditions.
- Explicit Solution Algorithms — The MacCormack explicit method has been incorporated in the code to yield efficient solutions for highly transient flows.
- Split-Flux Schemes — To provide robust solutions for highly transient flows with moving shocks, split-flux schemes were applied to both the MacCormack and the Beam and Warming algorithms.

To model inlet flows accurately, the code uses precise inlet- and exit-plane boundary conditions. For the exit plane, these include specified exit-plane pressures and corrected mass flow as a function of time. For the inflow boundary, these include a specified mach number for the fully started inlet and code adaptability to model inlet unstart. LAPIN utilizes both explicit and totally-implicit boundary conditions in the inlet code to provide totally-compatible numerical schemes.

The code includes a number of sophisticated engineering features for treating such real inlet phenomena as translating center bodies, throat bleed, moving ramps, and variable engine-bypass flow — all with real-time variation. The code, designed by use of the top-down modular approach, is highly interactive with the user. It has been verified against data from unsteady tests of axisymmetric and two-dimensional engine inlets over a wide range of free-stream and geometric conditions.

The program is written in FORTRAN IV for execution on the IBM 370 or the VAX-11/780 and contains approximately 6,100 lines of source code.

This program was written by M. O. Varner, W. R. Martindale, W. J. Phares, K. R. Kneile, and J. C. Adams, Jr., of Sverdrup Technology, Inc., for **Lewis Research Center**. *LEW-14324 /TN*

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Simulation of the Internal-Combustion Engine

This program adapts to the available information about a particular engine.

A mathematical model of the internal-combustion engine has been constructed and implemented as a computer program suitable for use on large digital computer systems. The ZMOTTO program calculates Otto-cycle performance parameters as well as working-fluid compositions and properties throughout the cycle for a number of consecutive cycles and for a variety of input parameters.

The model strikes a balance among three competing factors: (1) the desire for physical realism, (2) the extent of experimental information on the physical processes occurring in the engine, and (3) the capabilities of the present generation of computers. The result is a flexible and computationally economical model based on a system of ordinary differential equations for cylinder-averaged properties.

The computer program is capable of multicycle calculations, with some parameters varying from cycle to cycle, and has restart capabilities that enable the continuation of a sequence of cycle calculations or the recalculation of earlier cycles with altered assumptions. It can accommodate a broad spectrum of reactants, permit changes in physical properties, and offer a wide selection of alternative modeling functions without any reprogramming.

The program readily adapts to the amount of information available in a particular case because the model is actually a hierarchy of five models of differing complexity. The models range from simple, requiring only thermodynamic properties, to very complex, demanding full combustion kinetics, transport properties, and the flow characteristics of poppet valves.

The cycle calculations are based on the premise that heat transfer is expressible in terms of a heat-transfer coefficient and that the cylinder average of kinetic plus potential energies remains constant. Furthermore, during combustion the pressures of the burned and unburned gases are assumed to be equal and their heat-transfer areas are assumed to be proportional to their respective mass fractions. Although the model cannot resolve spatial gradients, it does not assume spatial uniformity.

The computer program ZMOTTO contains over 70 routines. It is written in standard FORTRAN IV and was tested on the IBM 370/3033, the IBM 360/67, and the Cray 1S computers.

This program was written by Frank J. Zeleznik and Bonnie J. McBride for **Lewis Research Center**. *LEW-14313 /TN*

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Customers in Canada, United States, and Mexico use this schedule. Other addresses should write for the price listing, number PR-360-4.

Prices effective January 1, 1988

Use this form ONLY to order reports designated as available from NTIS

MAIL ORDER TO: National Technical Information Service
U.S. DEPARTMENT OF COMMERCE
5265 Port Royal Road
Springfield, VA 22161

Send me the reports I have selected on this form. I have placed order numbers in appropriate blanks and have indicated the quantity. IF ADDRESS LABEL

Last Name: .....

Title: .....

Company/Organization: .....

Address: .....

.....

City/State/Zip: .....

Telephone Number: .....

METHOD OF PAYMENT

☐ Check enclosed payable to NTIS for $ .....

☐ Charge to my NTIS Deposit Account, No: ....

☐ Purchase order number: .....

Charge to: ☐ American Express ☐ VISA ☐ MasterCard

Card Number: .....

Expation date: .....

Signature: .....
(Required to validate order)

NTIS ORDER NUMBER (Use only for backup reports stated as available from NTIS)

NTIS Order Number	*Price**	*Quantity*	*Total Price*
.....	.....	.....	.....
.....	.....	.....	.....
.....	.....	.....	.....
.....	.....	.....	.....
.....	.....	.....	.....
		Shipping and handling fee	$3.00
		Total	.....

NTIS Order Form

NTIS Telephone Numbers

To Order Reports
(703) 487-4650

For Subscription Questions
(703) 487-4630

Other Information
(703) 487-4600

Editorial Questions
(703) 487-4805

Postage:
NTIS uses First Class Delivery, or equivalent service, on all shipping. For information about one day RUSH ordering, call (703) 487-4600.

NTIS PRICE CODE SCHEDULE *

This schedule gives the current values to the price codes cited in those Tech Notes having a backup report available from NTIS.

Microfiche
A01 . . . . . $6.95

Paper copy
A02 . . . . . 9.95
A03 . . . . . 12.50
A04 through A05. . . 14.95
A06 through A09 . . . 19.95
A10 through A13 . . . 25.95
A14 through A17 . . . 32.95
A18 through A21 . . . 38.95
A22 through A25 . . . 44.95
A99 . . . . . Call for price

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Address: . . . . . .

. . . . . .

City/State/Zip: . . . . . .

Telephone Number: . . . . . .

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☐ Charge to my NTIS Deposit Account, No: ....-.....

☐ Purchase order number: . . . . . .

Charge to: ☐ American Express ☐ VISA ☐ MasterCard

Card Number: . . . . . .

Expation date: . . . . . .

Signature: . . . . . .
(Required to validate order)

NTIS ORDER NUMBER (Use only for backup reports stated as available from NTIS)

NTIS Order Number	*Price**	*Quantity*	*Total Price*
. . . . .	. . . . .	. . . . .	. . . . .
. . . . .	. . . . .	. . . . .	. . . . .
. . . . .	. . . . .	. . . . .	. . . . .
. . . . .	. . . . .	. . . . .	. . . . .
. . . . .	. . . . .	. . . . .	. . . . .
		Shipping and handling fee	$3.00
		Total	. . . . .

- Agriculture & Food
- Computers
- Electrotechnology
- Energy
- Engineering
- Environmental Science & Technology
- Manufacturing, Machinery, & Tools
- Materials
- Medicine & Biology
- Natural Resources, Technology & Engineering
- Physical Sciences
- Transportation & Components

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Springfield, Va. 22161

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1913-1988

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